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No. 6

Bevel, Spiral and Worm Gearing

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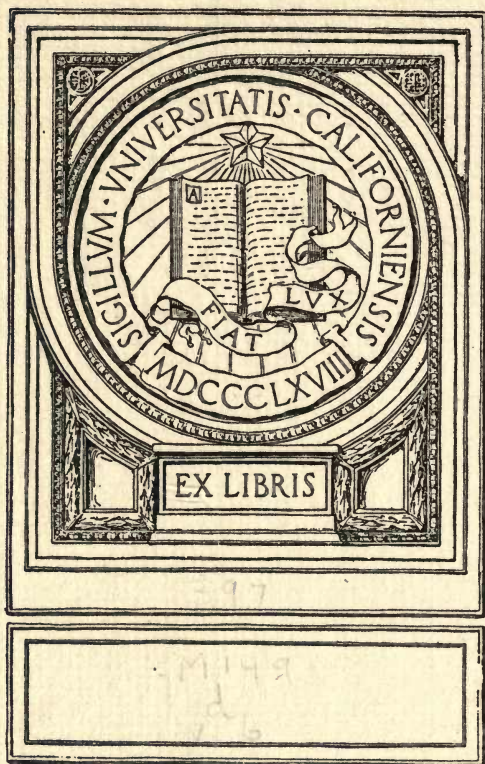
CONTENTS

| | |
|--|----|
| Rules and Formulas for Bevel Gear Calculations..... | 4 |
| Strength of Bevel Gears..... | 8 |
| Proportions of Bevel Gears..... | 9 |
| Bevel Gear Diagrams..... | 12 |
| Table for Determining the Outside Diameter of Bevel Gears..... | 14 |
| Rules and Formulas for Spiral Gear Calculations..... | 17 |
| Table Giving Lead of Spiral for Given Angle..... | 18 |
| Constants for Calculating Spiral Gears..... | 20 |
| Diagram for Finding Spiral Gear Cutter Numbers..... | 24 |
| Rules and Formulas for Worm Gearing Calculations..... | 25 |
| Worms and Worm Gearing..... | 26 |
| Worm Thread Helix Angles..... | 28 |

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MACHINERY'S DATA SHEET SERIES

COMPILED FROM MACHINERY'S MONTHLY DATA
SHEETS AND ARRANGED WITH
EXPLANATORY MATTER

No. 6

Bevel, Spiral and Worm Gearing

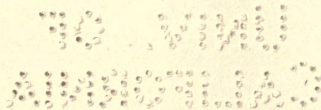
CONTENTS

| | |
|--|----|
| Rules and Formulas for Bevel Gear Calculations..... | 4 |
| Strength of Bevel Gears..... | 8 |
| Proportions of Bevel Gears..... | 9 |
| Bevel Gear Diagrams..... | 12 |
| Table for Determining the Outside Diameter of Bevel Gears..... | 14 |
| Rules and Formulas for Spiral Gear Calculations..... | 17 |
| Table Giving Lead of Spiral for Given Angle..... | 18 |
| Constants for Calculating Spiral Gears..... | 20 |
| Diagram for Finding Spiral Gear Cutter Numbers..... | 24 |
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| Worms and Worm Gearing..... | 26 |
| Worm Thread Helix Angles..... | 28 |

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In the following pages are compiled a number of diagrams and concise tables relating to bevel, spiral and worm gearing, carefully selected from MACHINERY's monthly Data Sheets, issued as supplements to the Engineering and Railway editions of MACHINERY since September, 1898. A number of additional tables also are included which are published here for the first time.

In order to enhance the value of the tables and diagrams, brief explanatory notes have been provided. In these notes references are made to articles which have appeared in MACHINERY, and to matter published in MACHINERY's Reference Series, giving additional information on the subject. These references will be of considerable value to readers who wish to make a more thorough study of the subject. In a note at the foot of each table reference is made to the page on which the explanatory note relating to the table appears.



BEVEL, SPIRAL AND WORM GEARING

Formulas for Bevel Gears

On pages 4 to 7, inclusive, are given complete rules and formulas for the calculation of bevel gearing, whether the shafts be at a right angle, at an acute angle, or at an obtuse angle with each other. Specific formulas for miter bevel gearing are also given, as well as for crown gears and internal bevel gears—the latter on page 7. The notation used in the formulas is easily understood by comparing the formula with the corresponding rule. The numbers given in the left-hand column are for convenient reference to any particular rule. The rules and formulas are given in the order in which they would ordinarily be used by a designer of bevel gearing.

Internal bevel gearing should be avoided except in cases where cast gears will be satisfactory, because it is practically impossible to cut internal bevel gearing. It may be possible on some forms of templet planing machines to produce internal bevel gears, if the pitch cone angle is not too great, but it is impossible on any form of generating machine. Internal bevel gearing can usually be avoided, and be replaced by external bevel gearing, by extending one of the shafts between which motion is to be transmitted, and mounting the gears in such a position that the required motion can be transmitted by a pair of ordinary bevel gears.

The following exceptions to, and modifications of, the rules given should be noted:

1. The Brown & Sharpe Mfg. Co. recommends that for shaping bevel gear teeth with a formed cutter, the cutting angle be determined by subtracting the *ad-*

dendum angle from the pitch cone angle, instead of subtracting the dedendum angle, as in Rule 15, page 5. In other words, the clearance at the bottom of the tooth is made uniform instead of tapering toward the vertex. This gives a somewhat closer approximation to the desired shape. This applies, of course, also to Rule 25.

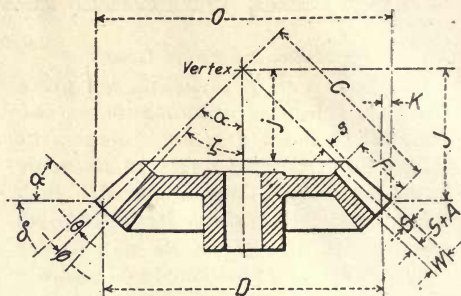
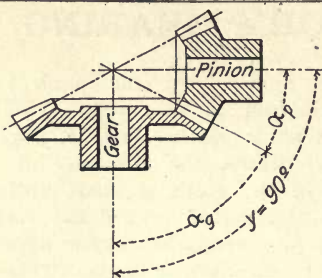
2. In generating machines (such as the Bilgram and the Gleason) it is often advisable to depart from the standard dimensions of gear teeth as given by Rules and Formulas 1 to 44. For instance, where the pinion is made of bronze and the gear of steel, the teeth of the former can be made wider and those of the latter correspondingly thinner, so as to somewhat nearly equalize the strength of the two. Again, where the pinion has few teeth and the gear many, it may be advisable to make the addendum on the pinion larger and the dedendum correspondingly smaller, reversing this on the gear, making the addendum smaller and the dedendum larger. This is done to avoid interference and consequent undercut on the flanks of pinions having a small number of teeth. Such changes are easily effected on generating machines, and instructions for doing this for any case will usually be furnished by the makers of the various machines. [MACHINERY, February, 1910, Derivation of Bevel Gear Formulas; MACHINERY's Reference Series No. 37, Bevel Gearing, Chapter I.]

Strength of Bevel Gears

A table, rules and formulas for the strength of bevel gears are given on page 8. The table and formulas are (Continued on page 11.)

RULES AND FORMULAS FOR BEVEL GEAR CALCULATIONS—I

Bevel Gears with Shafts at Right Angles.



Note: α_p = Pitch Cone Angle of Pinion
 α_g = Pitch Cone Angle of Gear
 N_p = Number of Teeth in Pinion, etc.

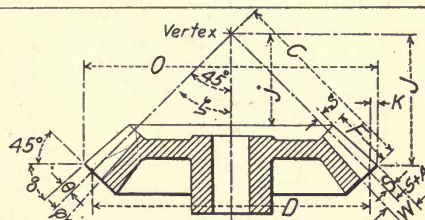
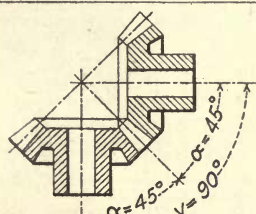
Use Rules and Formulas 1-21 in the order given.

| No. | To Find | Rule | Formula |
|-----|--|---|--------------------------------------|
| 1 | Pitch Cone Angle (or Edge Angle) of Pinion | Divide the number of teeth in the pinion by the number of teeth in the gear to get the tangent | $\tan \alpha_p = \frac{N_p}{N_g}$ |
| 2 | Pitch Cone Angle (or Edge Angle) of Gear | Divide the number of teeth in the gear by the number of teeth in the pinion to get the tangent | $\tan \alpha_g = \frac{N_g}{N_p}$ |
| 3 | Proof of Calculations for Pitch Cone Angles | The sum of the pitch cone angles of the pinion and gear equals 90 degrees | $\alpha_p + \alpha_g = 90^\circ$ |
| 4 | Pitch Diameter | Divide the number of teeth by the diametral pitch; or multiply the number of teeth by the circular pitch and divide by 3.1416 | $D = \frac{N}{P} = \frac{NP'}{\pi}$ |
| 5 | These dimensions are the same for both gear and pinion | Addendum | $S = \frac{1.0}{P} = 0.318P'$ |
| 6 | | Dedendum | $S+A = \frac{1.57}{P} = 0.368P'$ |
| 7 | | Whole Depth of Tooth Space | $W = \frac{2.157}{P} = 0.687P'$ |
| 8 | | Thickness of Tooth at Pitch Line | $T = \frac{1.571}{P} = \frac{P'}{2}$ |
| 9 | | Pitch Cone Radius | $C = \frac{D}{2 \times \sin \alpha}$ |
| 10 | | Addendum at Small End of Tooth | $s = S \times \frac{C-F}{C}$ |
| 11 | | Thickness of Tooth at Pitch Line at Small End | $t = T \times \frac{C-F}{C}$ |
| 12 | | Addendum Angle | $\tan \theta = \frac{S}{C}$ |
| 13 | | Dedendum Angle | $\tan \phi = \frac{S+A}{C}$ |

RULES AND FORMULAS FOR BEVEL GEAR CALCULATIONS—II

Bevel Gears with Shafts at Right Angles. (Continued).

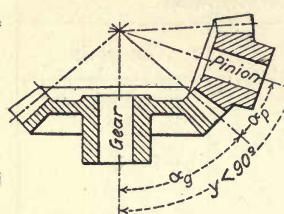
| No. | To Find | Rule | Formula |
|-----|--|--|---|
| 14 | Face Angle | Subtract the sum of the pitch cone and addendum angles from 90 degrees | $\delta = 90^\circ - (\alpha + \theta)$ |
| 15 | Cutting Angle | Subtract the dedendum angle from the pitch cone angle | $\zeta = \alpha - \phi$ |
| 16 | Angular Addendum | Multiply the addendum by the cosine of the pitch cone angle | $K = S \times \cos \alpha$ |
| 17 | Outside Diameter | Add twice the angular addendum to the pitch diameter | $O = D + 2K$ |
| 18 | Apex Distance | Multiply one-half the outside diameter by the tangent of the face angle | $J = \frac{O}{2} \times \tan \delta$ |
| 19 | Apex Distance at Small End of Tooth | Subtract the width of face from the pitch cone radius, divide the remainder by the pitch cone radius and multiply by the apex distance | $j = J \times \frac{C-F}{C}$ |
| 20 | Number of Teeth in Equivalent Spur Gear | Divide the number of teeth by the cosine of the pitch cone angle | $N' = \frac{N}{\cos \alpha}$ |
| 21 | Proof of Calculations by Rules Nos. 9, 12, 14, 16 and 17 | The outside diameter equals twice the pitch cone radius multiplied by the cosine of the face angle and divided by the cosine of the addendum angle | $O = \frac{2C \times \cos \delta}{\cos \theta}$ |

Mitre Bevel Gearing.

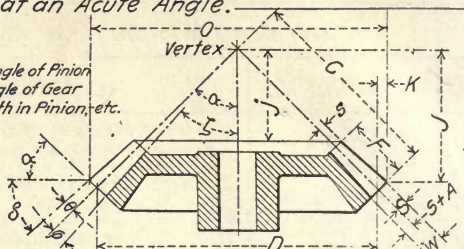
Use Rules and Formulas 22, 4-8, 23, 10-13, 24-26, 17-19, 27 and 21 in the order given. All dimensions thus obtained are the same for both gears of a pair

| No. | To Find | Rule | Formula |
|-----|---|---|------------------------------|
| 22 | Pitch Cone Angle | Pitch cone angle equals 45 degrees | $\alpha = 45^\circ$ |
| 23 | Pitch Cone Radius | Multiply the pitch diameter by 0.707 | $C = 0.707D$ |
| 24 | Face Angle | Subtract the addendum angle from 45° | $\delta = 45^\circ - \theta$ |
| 25 | Cutting Angle | Subtract the dedendum angle from 45 degrees | $\zeta = 45^\circ - \phi$ |
| 26 | Angular Addendum | Multiply the addendum by 0.707 | $K = 0.707 S$ |
| 27 | Number of Teeth in Equivalent Spur Gear | Multiply the number of teeth by 1.41 | $N' = 1.41 N$ |

RULES AND FORMULAS FOR BEVEL GEAR CALCULATIONS—III

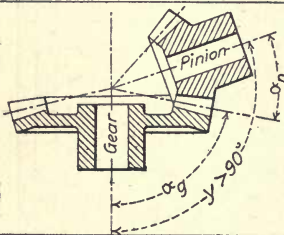
Bevel Gears with Shafts at an Acute Angle.

Note:
 α_p = Pitch Cone Angle of Pinion
 α_g = Pitch Cone Angle of Gear
 N_p = Number of Teeth in Pinion, etc.

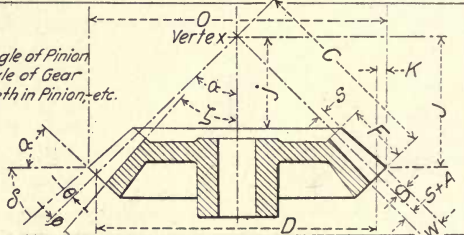


Use Rules and Formulas 28-30, and 4-21 in the order given.

| No. | To Find | Rule | Formula |
|-----|---|---|---|
| 28 | Pitch Cone Angle (or Edge Angle) of Pinion | Divide the sine of the center angle by the sum of the cosine of the center angle and the quotient of number of teeth in the gear divided by the number of teeth in the pinion; this gives the tangent | $\tan \alpha_p = \frac{\sin \gamma}{\frac{N_g}{N_p} + \cos \gamma}$ |
| 29 | Pitch Cone Angle (or Edge Angle) of Gear | Divide the sine of the center angle by the sum of the cosine of the center angle and the quotient of the number of teeth in the pinion divided by the number of teeth in the gear; this gives the tangent | $\tan \alpha_g = \frac{\sin \gamma}{\frac{N_p}{N_g} + \cos \gamma}$ |
| 30 | Proof of Calculations for Pitch Cone Angles | The sum of the pitch cone angles of the pinion and gear equals the center angle | $\alpha_p + \alpha_g = \gamma$ |

Bevel Gears with Shafts at an Obtuse Angle.

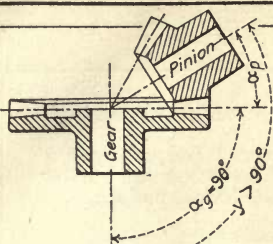
Note:
 α_p = Pitch Cone Angle of Pinion
 α_g = Pitch Cone Angle of Gear
 N_p = Number of Teeth in Pinion, etc.



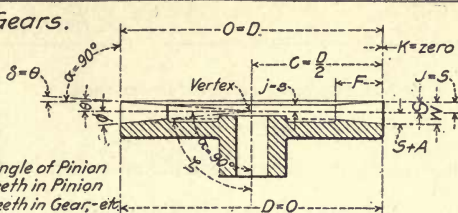
Use Rules and Formulas 31 and 32 as directed below.

| No. | To Find | Rule | Formula |
|-----|---|---|---|
| 31 | Pitch Cone Angle (or Edge Angle) of Pinion | Divide the sine of 180 degrees minus the center angle by the difference between the quotient of the number of teeth in the gear divided by the number of teeth in the pinion and the cosine of 180 degrees minus the center angle; this gives the tangent | $\tan \alpha_p = \frac{\sin (180^\circ - \gamma)}{\frac{N_g}{N_p} - \cos (180^\circ - \gamma)}$ |
| 32 | Whether Gear is a Regular Bevel Gear, a Crown Gear, or an Internal Bevel Gear | Add 90 degrees to the pitch cone angle of the pinion. If the sum is greater than the center angle use rules and formulas 33, 30 and 4-21 in the order given. If the sum equals the center angle see rules and formulas for crown gear. If the sum is less than the center angle see rules and formulas for internal bevel gear. | |
| 33 | Pitch Cone Angle (or Edge Angle) of Gear | Divide the sine of 180 degrees minus the center angle by the difference between the quotient of the number of teeth in the pinion divided by the number of teeth in the gear and the cosine of 180 degrees minus the center angle; this gives the tangent | $\tan \alpha_g = \frac{\sin (180^\circ - \gamma)}{\frac{N_p}{N_g} - \cos (180^\circ - \gamma)}$ |

RULES AND FORMULAS FOR BEVEL GEAR CALCULATIONS—IV



Crown Gears.

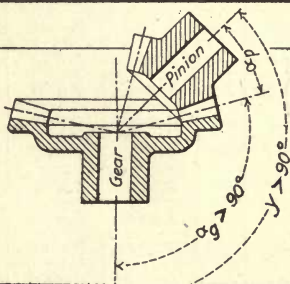


Note:

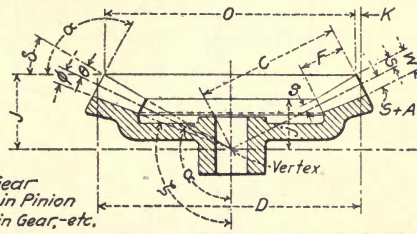
 α_p = Pitch Cone Angle of Pinion N_p = Number of Teeth in Pinion N_g = Number of Teeth in Gear, etc.

Use Rules 31 and 4-21 in the order given, for the pinion; use Rules 30, 4-8, 36, 10-13, 37, 15 and 38 in the order given for the crown gear; if dimensions for crown gear are known, to find center angle and dimensions of pinion, use rules and formulas 34, 35 and 4-21 in the order given

| No. | To Find | Rule | Formula |
|-----|--|--|-----------------------------------|
| 34 | Pitch Cone Angle (or Edge Angle) of Pinion | Divide the number of teeth in the pinion by the number of teeth in the gear; to get the sine | $\sin \alpha_p = \frac{N_p}{N_g}$ |
| 35 | Center Angle | Add 90 degrees to the pitch cone angle of the pinion | $y = 90^\circ + \alpha_p$ |
| 36 | Pitch Cone Radius | Divide the pitch diameter by 2 | $C = \frac{D}{2}$ |
| 37 | Face Angle of Gear | The face cone angle of the gear equals the addendum angle | $\delta_g = \theta$ |
| 38 | Number of Teeth in Equivalent Spur Gear | The teeth are equivalent in form to rack teeth | $N_g' = \text{infinity}$ |



Internal Bevel Gears.



Note:

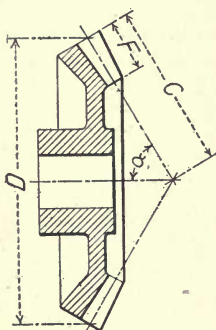
 δ_g = Face Angle of Gear N_p = Number of Teeth in Pinion N_g = Number of Teeth in Gear, etc.

Use Rules and Formulas 31 and 4-21 inclusive for the pinion; use Rules and Formulas 39, 30, 40, 41, 15, 42, 43, 18, 19, 44 and 21 in the order given for the gear

| No. | To Find | Rule | Formula |
|-----|--|---|--|
| 39 | Pitch Cone Angle (or Edge Angle) of Gear | Divide the sine of 180 degrees minus the center angle, by the difference between the cosine of 180 degrees minus the center angle and the quotient of the number of teeth in the pinion divided by the number of teeth in the gear; subtract the angle whose tangent is thus found from 180 degrees | $\tan \alpha_g = \frac{\sin (180-y)}{\cos (180-y) - \frac{N_p}{N_g}}$ $\alpha_g = 180 - \alpha_a$ |
| 40 | Pitch Cone Radius | Divide the pitch diameter by twice the sine of 180 degrees minus the pitch cone angle | $C = \frac{D_g}{2 \sin (180 - \alpha_g)}$ |
| 41 | Face Angle of Gear | Subtract 90 degrees from the sum of the pitch cone angle and the addendum angle | $\delta_g = \alpha_g + \theta - 90^\circ$ |
| 42 | Angular Addendum of Gear | Multiply the addendum by the cosine of 180 degrees minus the pitch cone angle | $K_g = S \times \cos (180 - \alpha_g)$ |
| 43 | Outside (or Edge) Diameter of Gear | Subtract twice the angular addendum from the pitch diameter | $O_g = D_g - 2K_g$ |
| 44 | Number of Teeth in Equivalent Internal Spur Gear | Divide the number of teeth by the cosine of 180 degrees minus the pitch cone angle | $N_g' = \frac{N_g}{\cos (180 - \alpha_g)}$ |

STRENGTH OF BEVEL GEARS

List of Reference Letters.

 D = pitch diameter of gear in inches. R = revolutions per minute. V = velocity in ft. per min. at pitch diameter. S_s = allowable static unit stress for material. S = allowable unit stress for material at given velocity. F = width of face. N' = No. of teeth in equivalent spur gear (See diagram). Y = outline factor (see table below) P = diametral pitch (if circular pitch is given, divide 3.1416 by circular pitch to obtain diametral pitch). C = pitch cone radius. W = maximum safe tangential load in pounds at pitch diameter. $H.P.$ = maximum safe horse power.

$$N' = \frac{\text{Number of teeth}}{\cos \alpha}$$

(Rule No. 20)

Table of Outline Factors (Y) for $14\frac{1}{2}^\circ$ and 20° Involute

| N' | Outline Factor = Y | | N' | Outline Factor = Y | |
|------|---|------------------------|------|---|------------------------|
| | $14\frac{1}{2}^\circ$ Involute (Std.) | 20° Involute | | $14\frac{1}{2}^\circ$ Involute (Std.) | 20° Involute |
| 12 | 0.210 | 0.245 | 27 | 0.314 | 0.349 |
| 13 | 0.220 | 0.261 | 30 | 0.320 | 0.358 |
| 14 | 0.226 | 0.276 | 34 | 0.327 | 0.371 |
| 15 | 0.236 | 0.289 | 38 | 0.336 | 0.383 |
| 16 | 0.242 | 0.295 | 43 | 0.346 | 0.396 |
| 17 | 0.251 | 0.302 | 50 | 0.352 | 0.408 |
| 18 | 0.261 | 0.308 | 60 | 0.358 | 0.421 |
| 19 | 0.273 | 0.314 | 75 | 0.364 | 0.434 |
| 20 | 0.283 | 0.320 | 100 | 0.371 | 0.446 |
| 21 | 0.289 | 0.327 | 150 | 0.377 | 0.459 |
| 23 | 0.295 | 0.333 | 300 | 0.383 | 0.471 |
| 25 | 0.305 | 0.339 | Rack | 0.390 | 0.484 |

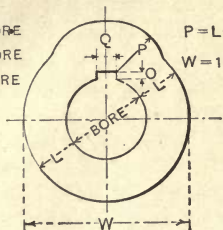
Use rules and formulas 45-48 in the order given

| No. | To Find | Rule | Formula |
|-----|--|--|--------------------------------------|
| 45 | Velocity in ft. per min. at the pitch diameter | Multiply the product of the diameter in inches and the number of revolutions per minute, by 0.262 | $V = 0.262 DR$ |
| 46 | Allowable unit stress at given velocity | Multiply the allowable static stress by 600 and divide the result by the velocity in feet per minute plus 600 | $S = S_s \times \frac{600}{600 + V}$ |
| 47 | Maximum safe tangential load at pitch diameter | Multiply together the allowable stress for the given velocity, the width of face, the tooth outline factor and the difference between the pitch cone radius and the width of face; divide the result by the product of the diametral pitch and the pitch cone radius | $W = \frac{SFY(C-F)}{PC}$ |
| 48 | Maximum safe Horse Power | Multiply the safe load at the pitch line by the velocity in feet per minute, and divide the result by 33,000 | $HP = \frac{WV}{33,000}$ |

PROPORTIONS OF BEVEL GEARS

STANDARD HUB

$Q = \frac{1}{4}$ OF BORE
 $O = \frac{1}{8}$ OF BORE
 $L = \frac{7}{16}$ OF BORE

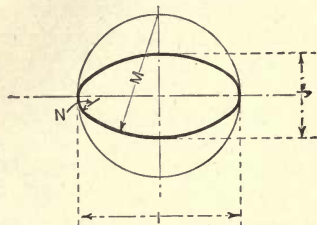


$P = L + \frac{1}{8}$
 $W = 1\frac{1}{8} \times \text{BORE}$

STANDARD OVAL ARM

NUMBER OF ARMS
 6 TO 24

6 TO 24
 30
 36
 42
 48
 54
 60
 66
 72
 78
 84
 90
 96
 102
 108
 114
 120
 126
 132
 138
 144
 150
 156
 162
 168
 174
 180
 186
 192
 198
 204
 210
 216
 222
 228
 234
 240

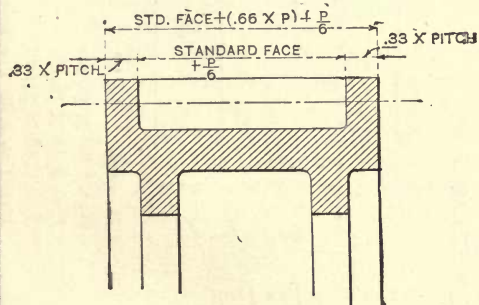


$J = \text{WIDTH OF ARM}$

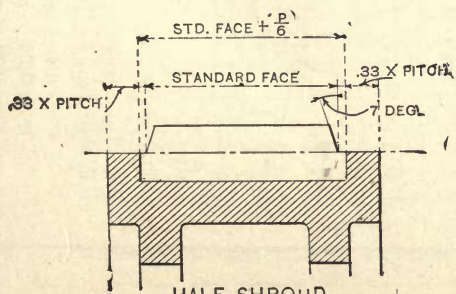
$J = \frac{1}{2}$ OF I
 $M = \frac{3}{4}$ OF I

Industrial Press, N.Y.

$N = \frac{1}{8}$ OF I



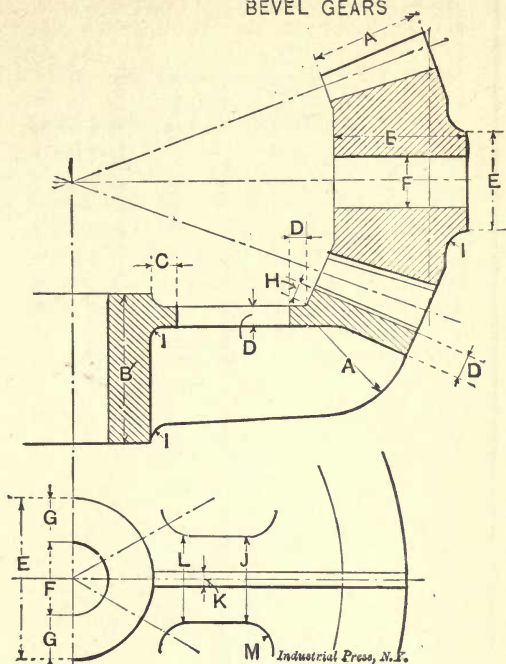
FULL SHROUD



HALF SHROUD

Industrial Press, N.Y.

BEVEL GEARS



BEVEL GEARS.

$$B = A + .25 \times \text{Pitch}$$

$$C = \text{At least } .25 \times L$$

$$D = .48 \times \text{Pitch}$$

$$E = 1.875 \times \text{Bore}$$

$$F = \text{Bore}$$

$$G = .4375 \times \text{Bore}$$

$$H = .45 \times \text{Pitch}$$

$$I = .25 \times \text{Pitch}$$

$$J = 2.30 \times \text{Pitch}$$

$$K = .40 \times \text{Pitch}$$

$$L = J + \frac{3}{4} \text{ inch per foot of Length}$$

$$M = .25 \times J$$

For Hub, See Upper Left-hand Sketch

For Number of Arms, See Upper Left-hand Sketch

$$B' = A + .05 \times \text{Diameter}$$

MITER GEARS

$$L = 1\frac{7}{8} \times \text{bore}$$

$$M = 0.40 \times \text{pitch}$$

$$N = 0.40 \times \text{pitch}$$

$$O = 0.25 \times \text{pitch}$$

$$P = 0.25 \times \text{pitch}$$

For hub and keyseat, see
page 9.

Pitch is at large end of
tooth.

Pitch diameter at large end
of tooth.

$$A = \frac{1}{4} \times B$$

$$B = 2.3 \times \text{pitch}$$

$$C = 0.30 \times \text{pitch}$$

$$D = 0.30 \times \text{pitch}$$

$$E = \text{about } 0.40 \times \text{pitch}$$

$$F = \frac{7}{16} \times \text{bore}$$

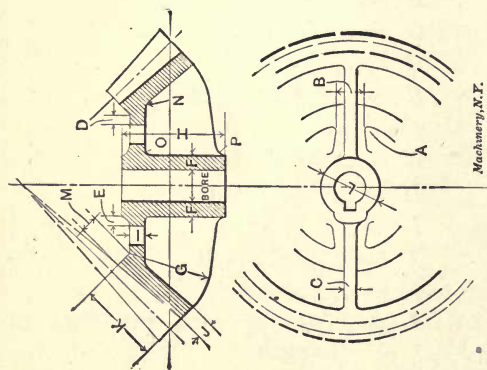
$$G = \text{face } K$$

$$H = \text{face } K + \frac{1}{8} \text{ of pitch}$$

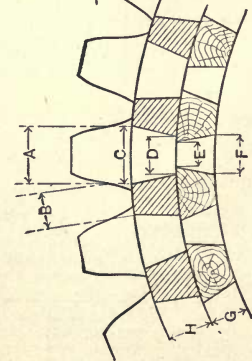
$$I = 0.48 \times \text{pitch}$$

$$J = 0.48 \times \text{pitch}$$

$$K = \text{face}$$



SPUR MORTISE GEARS



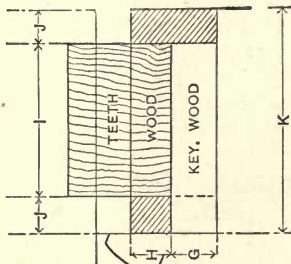
$$A = 0.55 \times \text{pitch}$$

$$B = 0.45 \times \text{pitch}$$

$$C = 0.40 \times \text{pitch}$$

$$D = 0.32 \times \text{pitch}$$

$$E = 0.27 \times \text{pitch}$$



$$F = 0.32 \times \text{pitch}$$

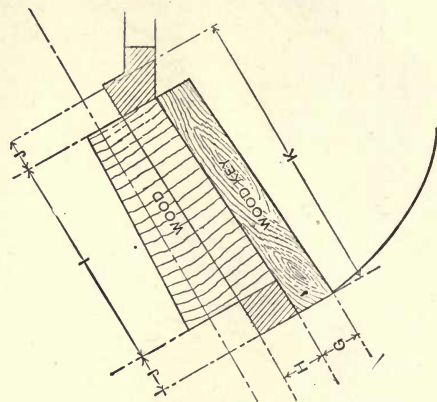
$$G = 0.48 \times \text{pitch}$$

$$H = 0.48 \times \text{pitch}$$

$$J = 0.45 \times \text{pitch}$$

$$K = 1 + 0.90 \times \text{pitch}$$

BEVEL MORTISE GEARS



$$A = 0.55 \times \text{pitch}$$

$$B = 0.45 \times \text{pitch}$$

$$C = 0.40 \times \text{pitch}$$

$$D = 0.32 \times \text{pitch}$$

$$E = 0.27 \times \text{pitch}$$

$$F = 0.32 \times \text{pitch}$$

$$G = 0.48 \times \text{pitch}$$

$$H = 0.50 \times \text{pitch}$$

$$J = 0.45 \times \text{pitch}$$

$$K = 1 + 0.90 \times \text{pitch}$$

founded on the Lewis method, and make it possible to quickly calculate the strength of bevel gears. The formulas given are based on the use of the diametral pitch of the gear, and the constants Y given in the table for use in the formulas are valid only when the diametral pitch is employed. If the circular pitch is given, it should be transformed into diametral pitch by dividing 3.1416 by the circular pitch. The formulas 45 to 48 make it possible to determine the horsepower which can be transmitted by a gear of a given pitch diameter and a given diametral pitch, when the number of revolutions per minute at which the gear is running is known. The formulas should be used in the order given. The only factor that need be assumed in these calculations is the allowable static unit stress for the material in the gear. For ordinary workmanship this factor may be assumed to be 6000 pounds per square inch for cast iron, 9000 for phosphor-bronze, and 15,000 for steel. For high-grade workmanship these factors may be increased to 8000, 12,000 and 20,000, respectively.

As an example, assume that it is required to find the horsepower which it is permissible to transmit by a bevel gear having 15-inch pitch diameter, 4 diametral pitch, making 100 revolutions per minute, and having a width of face of $1\frac{1}{2}$ inch, if the teeth are cut according to the $14\frac{1}{2}$ -degree involute system. The gear is made of steel and the allowable static unit stress for the material may, therefore, be assumed to be 15,000 pounds per square inch. We now first insert the values of the pitch diameter and the revolutions per minute in Formula (45) and thus find the velocity in feet per minute at the pitch diameter. We then insert this velocity, as found in Formula (45), together with the allowable static unit stress, in Formula (46), and find then the allowable unit stress at the given velocity. This unit stress is now inserted in Formula (47)

together with the width of face, the outline factor Y (which is found from the outline table to be 0.358 for 60

teeth), the factor $\frac{C - F}{C}$, and the diam-

etral pitch, and in this way we find the maximum safe tangential load W . Finally, by inserting the value of W just found and the value of V found from Formula (45), in Formula (48), we determine the maximum safe horsepower which can be transmitted by the gear. The numerical calculations are easily carried out, and it is not necessary to repeat them here.

Those familiar with the Lewis formula will note that Rule and Formula (47) is the same as for spur gears with the

exception of the additional factor $\frac{C - F}{C}$.

This factor is an approximate one which expresses the ratio of the strength of a bevel gear to that of a spur gear of the same pitch and number of teeth, the decrease being due to the fact that the pitch grows finer toward the vertex. This factor is approximate only, and should not be used for cases in which F is more than $\frac{1}{3} C$; but since no bevel gears should be made in which F is more than $\frac{1}{3} C$, the rule is of universal application for good practice. As the width of face is made greater in proportion to the pitch cone radius, the increase of strength obtained thereby grows proportionately smaller and smaller, as may be easily proved by analysis and calculation. Actually, the advantage of increasing the width of face is even less than is indicated by calculation, since the unavoidable deflection of the shaft is sure at one time or another to throw practically the whole load on the weak inner ends of the teeth, which thus have to carry the load without help from the large pitch at the outer ends. [MACHINERY, December, 1906, Strength of Gears; MACHINERY'S Reference Series No. 37, Bevel Gearing, Chapter IV.]

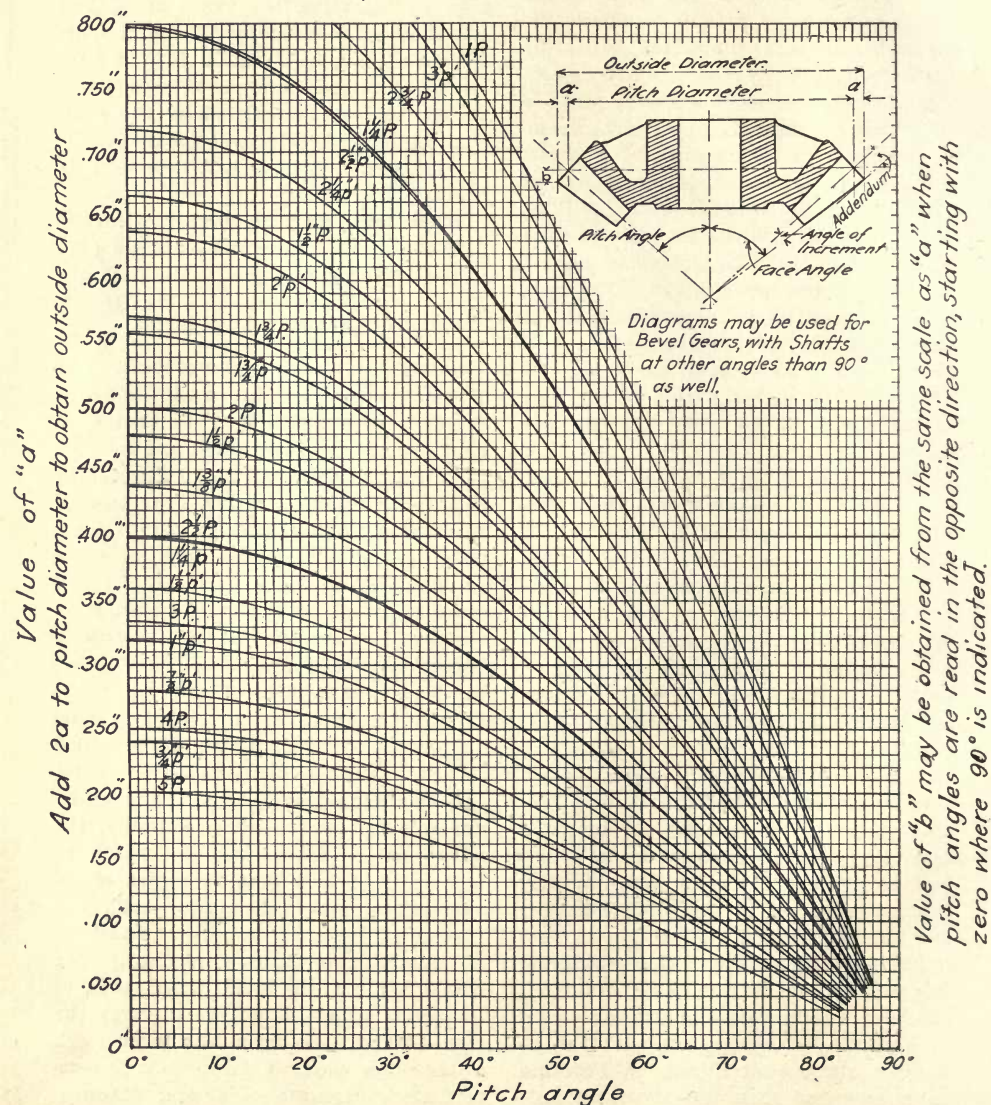
BEVEL GEAR DIAGRAMS—I

Curve Sheet for obtaining the outside diameter of cut bevel gears

$$\text{standard addendum} = \frac{1}{p} = 0.3183 p'$$

P = diametral pitch

p' = circular pitch



BEVEL GEAR DIAGRAMS—II

Diagram for obtaining the face angle of cut bevel gears
 Standard addendum = $0.3183 \times \text{circular pitch}$

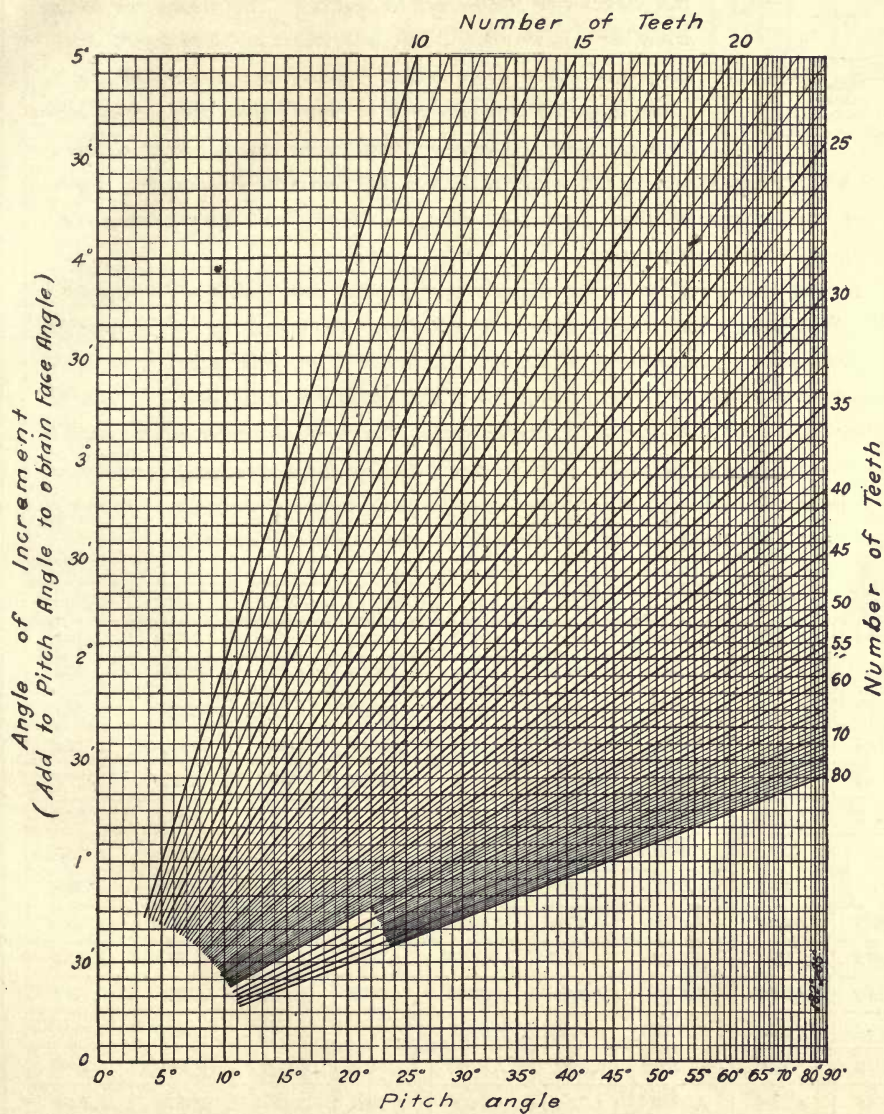
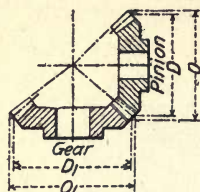


TABLE FOR DETERMINING THE OUTSIDE DIAMETER OF BEVEL GEARS—I



Tables I and II are the diameter increments for standard right angle bevel gears, which added to the pitch diameter (D and D_p) give the outside diameters (O and O_p). The tables are calculated for 1 diametral pitch, standard involute teeth, and cover the ratios from miters to gears and pinions of 10 to 1.

With the pitch and numbers of teeth known the outside diameters of a pair of standard bevel gears are found by simple calculation, using the factors here given. To find the diameter increments, first get the ratio between the bevel gear and pinion, and then divide the increments for that ratio by the given pitch.

For example: Find the outside diameters of a pair of bevel gears of 75 and 20 teeth, 6 diametral pitch. Dividing the number of teeth in the gear by the number of teeth in the pinion gives a ratio of 3.75 to 1. In table II the diameter increments for a gear and pinion of 1 diametral pitch of this ratio are 0.515 and 1.933. Dividing each by 6 gives 0.086 and 0.322 respectively. The pitch diameter of the gear is 12.500 inches and of the pinion 3.333 inches. Adding the diameter increments to the gear and pinion pitch diameters gives 12.586 inches for outside diameter of the gear and 3.655 inches for the outside diameter of the pinion.

Table I.

| Ratio | Gear | Pinion | Ratio | Gear | Pinion | Ratio | Gear | Pinion |
|-------|-------|--------|-------|-------|--------|-------|-------|--------|
| 1.000 | 1.414 | 1.414 | 1.400 | 1.162 | 1.627 | 1.800 | 0.971 | 1.748 |
| 1.025 | 1.396 | 1.431 | 1.425 | 1.149 | 1.636 | 1.825 | 0.961 | 1.754 |
| 1.050 | 1.380 | 1.448 | 1.450 | 1.135 | 1.646 | 1.850 | 0.951 | 1.760 |
| 1.075 | 1.362 | 1.464 | 1.475 | 1.122 | 1.655 | 1.875 | 0.941 | 1.765 |
| 1.100 | 1.345 | 1.480 | 1.500 | 1.109 | 1.664 | 1.900 | 0.931 | 1.770 |
| 1.125 | 1.328 | 1.494 | 1.525 | 1.096 | 1.672 | 1.925 | 0.922 | 1.775 |
| 1.150 | 1.312 | 1.509 | 1.550 | 1.084 | 1.680 | 1.950 | 0.912 | 1.780 |
| 1.175 | 1.296 | 1.523 | 1.575 | 1.072 | 1.688 | 1.975 | 0.903 | 1.784 |
| 1.200 | 1.280 | 1.536 | 1.600 | 1.060 | 1.696 | 2.000 | 0.894 | 1.790 |
| 1.225 | 1.264 | 1.549 | 1.625 | 1.047 | 1.703 | 2.025 | 0.885 | 1.793 |
| 1.250 | 1.249 | 1.561 | 1.650 | 1.036 | 1.710 | 2.050 | 0.876 | 1.797 |
| 1.275 | 1.234 | 1.573 | 1.675 | 1.025 | 1.717 | 2.075 | 0.868 | 1.801 |
| 1.300 | 1.219 | 1.585 | 1.700 | 1.014 | 1.723 | 2.100 | 0.860 | 1.805 |
| 1.325 | 1.204 | 1.596 | 1.725 | 1.003 | 1.730 | 2.125 | 0.851 | 1.809 |
| 1.350 | 1.190 | 1.607 | 1.750 | 0.992 | 1.736 | 2.150 | 0.843 | 1.813 |
| 1.375 | 1.176 | 1.617 | 1.775 | 0.982 | 1.742 | 2.175 | 0.835 | 1.817 |

TABLE FOR DETERMINING THE OUTSIDE DIAMETER OF BEVEL GEARS—II

Table II.

| <i>Ratio</i> | <i>Gear</i> | <i>Pinion</i> | <i>Ratio</i> | <i>Gear</i> | <i>Pinion</i> | <i>Ratio</i> | <i>Gear</i> | <i>Pinion</i> |
|--------------|-------------|---------------|--------------|-------------|---------------|--------------|-------------|---------------|
| 2.200 | 0.828 | 1.821 | 3.90 | 0.497 | 1.937 | 6.50 | 0.304 | 1.977 |
| 2.225 | 0.820 | 1.824 | 3.95 | 0.491 | 1.940 | 6.60 | 0.299 | 1.977 |
| 2.250 | 0.812 | 1.827 | 4.00 | 0.485 | 1.940 | 6.70 | 0.295 | 1.978 |
| 2.275 | 0.805 | 1.831 | 4.05 | 0.479 | 1.941 | 6.80 | 0.291 | 1.979 |
| 2.30 | 0.797 | 1.834 | 4.10 | 0.473 | 1.943 | 6.90 | 0.287 | 1.979 |
| 2.35 | 0.783 | 1.840 | 4.15 | 0.468 | 1.944 | 7.00 | 0.283 | 1.980 |
| 2.40 | 0.770 | 1.846 | 4.20 | 0.463 | 1.945 | 7.10 | 0.279 | 1.980 |
| 2.45 | 0.755 | 1.851 | 4.25 | 0.458 | 1.947 | 7.20 | 0.275 | 1.981 |
| 2.50 | 0.743 | 1.857 | 4.30 | 0.453 | 1.948 | 7.30 | 0.271 | 1.981 |
| 2.55 | 0.730 | 1.862 | 4.35 | 0.448 | 1.949 | 7.40 | 0.268 | 1.982 |
| 2.60 | 0.718 | 1.867 | 4.40 | 0.443 | 1.950 | 7.50 | 0.264 | 1.982 |
| 2.65 | 0.706 | 1.871 | 4.45 | 0.438 | 1.951 | 7.60 | 0.261 | 1.983 |
| 2.70 | 0.694 | 1.875 | 4.50 | 0.434 | 1.952 | 7.70 | 0.257 | 1.983 |
| 2.75 | 0.683 | 1.880 | 4.55 | 0.429 | 1.953 | 7.80 | 0.254 | 1.983 |
| 2.80 | 0.672 | 1.883 | 4.60 | 0.425 | 1.954 | 7.90 | 0.251 | 1.984 |
| 2.85 | 0.662 | 1.887 | 4.65 | 0.420 | 1.955 | 8.00 | 0.248 | 1.984 |
| 2.90 | 0.652 | 1.890 | 4.70 | 0.416 | 1.956 | 8.10 | 0.245 | 1.985 |
| 2.95 | 0.642 | 1.894 | 4.75 | 0.411 | 1.957 | 8.20 | 0.242 | 1.985 |
| 3.00 | 0.632 | 1.897 | 4.80 | 0.407 | 1.958 | 8.30 | 0.239 | 1.985 |
| 3.05 | 0.623 | 1.900 | 4.85 | 0.404 | 1.959 | 8.40 | 0.236 | 1.986 |
| 3.10 | 0.614 | 1.903 | 4.90 | 0.400 | 1.960 | 8.50 | 0.234 | 1.986 |
| 3.15 | 0.605 | 1.906 | 5.00 | 0.392 | 1.961 | 8.60 | 0.231 | 1.986 |
| 3.20 | 0.596 | 1.909 | 5.10 | 0.385 | 1.962 | 8.70 | 0.228 | 1.986 |
| 3.25 | 0.588 | 1.911 | 5.20 | 0.377 | 1.964 | 8.80 | 0.225 | 1.987 |
| 3.30 | 0.580 | 1.914 | 5.30 | 0.370 | 1.965 | 8.90 | 0.223 | 1.987 |
| 3.35 | 0.571 | 1.916 | 5.40 | 0.364 | 1.966 | 9.00 | 0.220 | 1.987 |
| 3.40 | 0.564 | 1.918 | 5.50 | 0.357 | 1.967 | 9.10 | 0.218 | 1.988 |
| 3.45 | 0.557 | 1.921 | 5.60 | 0.351 | 1.968 | 9.20 | 0.216 | 1.988 |
| 3.50 | 0.550 | 1.923 | 5.70 | 0.345 | 1.970 | 9.30 | 0.213 | 1.988 |
| 3.55 | 0.542 | 1.925 | 5.80 | 0.340 | 1.971 | 9.40 | 0.211 | 1.988 |
| 3.60 | 0.535 | 1.927 | 5.90 | 0.334 | 1.972 | 9.50 | 0.209 | 1.989 |
| 3.65 | 0.528 | 1.929 | 6.00 | 0.329 | 1.973 | 9.60 | 0.207 | 1.989 |
| 3.70 | 0.521 | 1.931 | 6.10 | 0.323 | 1.974 | 9.70 | 0.205 | 1.989 |
| 3.75 | 0.515 | 1.933 | 6.20 | 0.318 | 1.975 | 9.80 | 0.203 | 1.989 |
| 3.80 | 0.509 | 1.934 | 6.30 | 0.313 | 1.975 | 9.90 | 0.201 | 1.990 |
| 3.85 | 0.503 | 1.936 | 6.40 | 0.309 | 1.976 | 10.00 | 0.198 | 1.990 |

Proportions of Bevel Gears

Various forms may be given to the blanks or wheels on which bevel gear teeth are cut, depending on the size, material, service, etc., to be provided for. The pinion type of blank is mostly used for gears of a small number of teeth and small pitch cone angle. When the diameter of the bore comes too near to the bottoms of the teeth at the small end, it is customary to omit the usual recess in the front face. For gears of a larger number of teeth, the web type is appropriate. This does not require to be finished all over, as the sides of the web, the outside diameter of the hub, and the under side of the rim may be left rough if desired.

A gear suitable for very heavy work should have the web reinforced by ribs. The web may be cut out so that the rim is supported by T-shaped arms, as shown in the engraving on page 9. This makes a very stiff wheel and at the same time a very light one, when its strength is considered. Where the pitch cone angle is so great that the strengthening rib would be rather narrow at the flange, it may be given the rounded form shown, the radius A being equal to the face of the teeth.

The question of alignment of the shafts should be considered in deciding on the width of face of the gear. Making the width of the face more than one-third of the pitch cone radius adds practically nothing to the strength of the gear even theoretically, since the added portion is progressively weaker as the tooth is lengthened, as has already been explained. In addition to this, there is the danger that through springing of the shafts or poor workmanship, the load will be thrown onto the weak end of the tooth, thus fracturing it. For this reason it may be laid down as a definite rule that there is nothing to be gained by making the face of the bevel gear more than one-third of the pitch cone radius.

The Brown & Sharpe Mfg. Co., in one

of its publications, gives a rule for the maximum width of face allowable for a given pitch. The width of face should not exceed five times the circular pitch, or 16 divided by the diametral pitch. This rule is also rational since the danger to the teeth from the misalignment of the shaft increases both with the width of face and with the decrease of the size of the tooth, so that both of these should be reckoned with. In designing gearing it is well to check the width of face from the rule relating to the pitch cone radius and that relating to the pitch as well, to see that it does not exceed the maximum allowed by either.

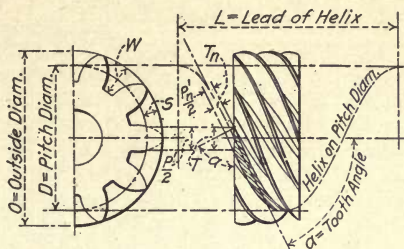
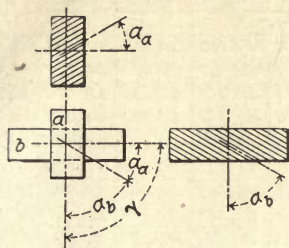
On page 9 are given formulas for the proportioning of bevel gears. The dimensions found by these formulas may, of course, have to be varied for individual requirements, but the formulas will serve as a guide for ordinary conditions. On the same page are also given dimensions for shrouded spur gears which will be found suitable for ordinary requirements. On page 10 are given proportions for miter gears, and for both spur and bevel mortise gears with wooden teeth. Gears of this latter type are, of course, seldom used in modern designs. [MACHINERY'S Reference Series No. 37, Bevel Gearing, Chapter V, Design of Bevel Gears.]

Diagrams for Bevel Gear Dimensions

Such data as the angle of increment, the outside diameter and the projection of the extreme edge of the teeth beyond the pitch circle in bevel gears may conveniently be found from the diagrams given on pages 12 and 13. The best way of explaining the diagrams is to take an example, such for instance, as the following: Find the outside diameter, face angle, and "backing" b of a bevel gear with 40 teeth, whose pitch angle is 56 degrees 59 minutes, 2 diametral pitch, and 20 inches pitch diam-

(Continued on page 27.)

RULES AND FORMULAS FOR SPIRAL GEAR CALCULATIONS



| No. | To Find | Rule | Formula |
|-----|---|---|---|
| 1 | Relation between Shaft and Tooth Angles | The sum of the tooth angles of a pair of mating helical gears is equal to the shaft angle. | $\gamma = \alpha_a + \alpha_b$ |
| 2 | Pitch Diameter | Divide the number of teeth by the product of the normal pitch and the cosine of the tooth angle. | $D = \frac{N}{P_n \cos \alpha}$ |
| 3 | Center Distance | Add together the pitch diameters of the two gears and divide by 2. | $C = \frac{D_a + D_b}{2}$ |
| 4 | Checking Calculations in (2) and (3) | To prove the calculations for pitch diameters and center distance, multiply the number of teeth in the first gear by the tangent of the tooth angle of that gear, and add the number of teeth in the second gear to the product; the sum should equal twice the product of the center distance multiplied by the normal diametral pitch, multiplied by the sine of the tooth angle of the first gear. | $N_b + (N_a \times \tan \alpha_a) = 2CP_n \times \sin \alpha_a$ |
| 5 | No. of Teeth for which to Select Cutter | Divide the number of teeth in the gear by the cube of the cosine of the tooth angle. | $N' = \frac{N}{(\cos \alpha)^3}$ |
| 6 | Lead of Tooth Helix | Multiply the pitch diameter by 3.1416 times the cotangent of the tooth angle. | $L = \pi D \cot \alpha$ |
| 7 | Addendum | Divide 1 by the normal diametral pitch. | $S = \frac{1}{P_n}$ |
| 8 | Whole Depth of Tooth | Divide 2.157 by the normal diametral pitch. | $W = \frac{2.157}{P_n}$ |
| 9 | Normal Tooth Thickness at Pitch Line | Divide 1.571 by the normal diametral pitch. | $T_n = \frac{1.571}{P_n}$ |
| 10 | Outside Diameter | Add twice the addendum to the pitch diameter. | $O = D + 2S$ |

TABLE GIVING LEAD OF SPIRAL FOR GIVEN ANGLE—I

| Deg. | 0' | 6' | 12' | 18' | 24' | 30' | 36' | 42' | 48' | 54' | 60' | |
|--------------------------|---------|----------|---------|---------|---------|---------|---------|---------|---------|---------|---------|------|
| L = lead for diameter 1. | | | | | | | | | | | | |
| 0 | Inf. | 1800.001 | 899.997 | 599.994 | 449.993 | 359.992 | 299.990 | 257.130 | 224.986 | 199.983 | 179.982 | 89 |
| 1 | 179.982 | 163.616 | 149.978 | 138.438 | 128.545 | 119.973 | 112.471 | 105.851 | 99.967 | 94.702 | 89.964 | 88 |
| 2 | 89.964 | 85.676 | 81.778 | 78.219 | 74.956 | 71.954 | 69.183 | 66.617 | 64.235 | 62.016 | 59.945 | 87 |
| 3 | 59.945 | 58.008 | 56.191 | 54.485 | 52.879 | 51.365 | 49.934 | 48.581 | 47.299 | 46.082 | 44.927 | 86 |
| 4 | 44.927 | 43.827 | 42.780 | 41.782 | 40.829 | 39.918 | 39.046 | 38.212 | 37.412 | 36.645 | 35.909 | 85 |
| 5 | 35.909 | 35.201 | 34.520 | 33.866 | 33.235 | 32.627 | 32.040 | 31.475 | 30.928 | 30.400 | 29.890 | 84 |
| 6 | 29.890 | 29.397 | 28.919 | 28.456 | 28.008 | 27.573 | 27.152 | 26.743 | 26.346 | 25.961 | 25.586 | 83 |
| 7 | 25.586 | 25.222 | 24.868 | 24.524 | 24.189 | 23.863 | 23.545 | 23.236 | 22.934 | 22.640 | 22.354 | 82 |
| 8 | 22.354 | 22.074 | 21.801 | 21.535 | 21.275 | 21.021 | 20.773 | 20.530 | 20.293 | 20.062 | 19.835 | 81 |
| 9 | 19.835 | 19.614 | 19.397 | 19.185 | 18.977 | 18.773 | 18.574 | 18.379 | 18.188 | 18.000 | 17.817 | 80 |
| 10 | 17.817 | 17.637 | 17.460 | 17.287 | 17.117 | 16.950 | 16.787 | 16.626 | 16.469 | 16.314 | 16.162 | 79 |
| 11 | 16.162 | 16.013 | 15.866 | 15.722 | 15.581 | 15.441 | 15.305 | 15.170 | 15.038 | 14.908 | 14.780 | 78 |
| 12 | 14.780 | 14.654 | 14.530 | 14.409 | 14.289 | 14.171 | 14.055 | 13.940 | 13.828 | 13.717 | 13.608 | 77 |
| 13 | 13.608 | 13.500 | 13.394 | 13.290 | 13.187 | 13.086 | 12.986 | 12.887 | 12.790 | 12.695 | 12.600 | 76 |
| 14 | 12.600 | 12.507 | 12.415 | 12.325 | 12.237 | 12.148 | 12.061 | 11.975 | 11.890 | 11.807 | 11.725 | 75 |
| 15 | 11.725 | 11.643 | 11.563 | 11.484 | 11.405 | 11.328 | 11.252 | 11.177 | 11.102 | 11.029 | 10.956 | 74 |
| 16 | 10.956 | 10.884 | 10.813 | 10.743 | 10.674 | 10.606 | 10.538 | 10.471 | 10.406 | 10.340 | 10.276 | 73 |
| 17 | 10.276 | 10.212 | 10.149 | 10.086 | 10.025 | 9.964 | 9.904 | 9.844 | 9.785 | 9.727 | 9.669 | 72 |
| 18 | 9.669 | 9.612 | 9.555 | 9.499 | 9.444 | 9.389 | 9.335 | 9.281 | 9.228 | 9.176 | 9.124 | 71 |
| 19 | 9.124 | 9.072 | 9.021 | 8.971 | 8.921 | 8.872 | 8.823 | 8.774 | 8.726 | 8.679 | 8.631 | 70 |
| 20 | 8.631 | 8.585 | 8.539 | 8.493 | 8.447 | 8.403 | 8.358 | 8.314 | 8.270 | 8.227 | 8.184 | 69 |
| 21 | 8.184 | 8.142 | 8.099 | 8.058 | 8.016 | 7.975 | 7.935 | 7.894 | 7.855 | 7.815 | 7.776 | 68 |
| 22 | 7.776 | 7.737 | 7.698 | 7.660 | 7.622 | 7.584 | 7.547 | 7.510 | 7.474 | 7.437 | 7.401 | 67 |
| 23 | 7.401 | 7.365 | 7.330 | 7.295 | 7.260 | 7.225 | 7.191 | 7.157 | 7.123 | 7.089 | 7.056 | 66 |
| 24 | 7.056 | 7.023 | 6.990 | 6.958 | 6.926 | 6.894 | 6.862 | 6.830 | 6.799 | 6.768 | 6.737 | 65 |
| 25 | 6.737 | 6.707 | 6.676 | 6.646 | 6.617 | 6.586 | 6.557 | 6.528 | 6.499 | 6.470 | 6.441 | 64 |
| 26 | 6.441 | 6.413 | 6.385 | 6.357 | 6.329 | 6.300 | 6.274 | 6.246 | 6.219 | 6.192 | 6.166 | 63 |
| 27 | 6.166 | 6.139 | 6.113 | 6.087 | 6.061 | 6.035 | 6.009 | 5.984 | 5.959 | 5.933 | 5.908 | 62 |
| 28 | 5.908 | 5.884 | 5.859 | 5.835 | 5.810 | 5.786 | 5.762 | 5.738 | 5.715 | 5.691 | 5.668 | 61 |
| 29 | 5.668 | 5.644 | 5.621 | 5.598 | 5.575 | 5.553 | 5.530 | 5.508 | 5.486 | 5.463 | 5.441 | 60 |
| 30 | 5.441 | 5.420 | 5.398 | 5.376 | 5.355 | 5.333 | 5.312 | 5.291 | 5.270 | 5.249 | 5.228 | 59 |
| 31 | 5.228 | 5.208 | 5.187 | 5.167 | 5.147 | 5.127 | 5.107 | 5.087 | 5.067 | 5.047 | 5.028 | 58 |
| 32 | 5.028 | 5.008 | 4.989 | 4.969 | 4.950 | 4.931 | 4.912 | 4.894 | 4.875 | 4.856 | 4.838 | 57 |
| 33 | 4.838 | 4.819 | 4.801 | 4.783 | 4.764 | 4.746 | 4.728 | 4.711 | 4.693 | 4.675 | 4.658 | 56 |
| 34 | 4.658 | 4.640 | 4.623 | 4.605 | 4.588 | 4.571 | 4.554 | 4.537 | 4.520 | 4.503 | 4.487 | 55 |
| 35 | 4.487 | 4.470 | 4.453 | 4.437 | 4.421 | 4.404 | 4.388 | 4.372 | 4.356 | 4.340 | 4.324 | 54 |
| 36 | 4.324 | 4.308 | 4.292 | 4.277 | 4.261 | 4.246 | 4.230 | 4.215 | 4.199 | 4.184 | 4.169 | 53 |
| 37 | 4.169 | 4.154 | 4.139 | 4.124 | 4.109 | 4.094 | 4.079 | 4.065 | 4.050 | 4.036 | 4.021 | 52 |
| 38 | 4.021 | 4.007 | 3.992 | 3.978 | 3.964 | 3.950 | 3.935 | 3.921 | 3.907 | 3.893 | 3.880 | 51 |
| 39 | 3.880 | 3.866 | 3.852 | 3.838 | 3.825 | 3.811 | 3.798 | 3.784 | 3.771 | 3.757 | 3.744 | 50 |
| 40 | 3.744 | 3.731 | 3.718 | 3.704 | 3.691 | 3.678 | 3.665 | 3.652 | 3.640 | 3.627 | 3.614 | 49 |
| 41 | 3.614 | 3.601 | 3.589 | 3.576 | 3.563 | 3.551 | 3.538 | 3.526 | 3.514 | 3.501 | 3.489 | 48 |
| 42 | 3.489 | 3.477 | 3.465 | 3.453 | 3.440 | 3.428 | 3.416 | 3.405 | 3.393 | 3.381 | 3.369 | 47 |
| 43 | 3.369 | 3.358 | 3.346 | 3.334 | 3.322 | 3.311 | 3.299 | 3.287 | 3.276 | 3.265 | 3.253 | 46 |
| 44 | 3.253 | 3.242 | 3.231 | 3.219 | 3.208 | 3.197 | 3.186 | 3.175 | 3.164 | 3.153 | 3.142 | 45 |
| | 60' | 54' | 48' | 42' | 36' | 30' | 24' | 18' | 12' | 6' | 0' | Deg. |

To find the lead for a given angle of spiral, with the axis of the work, read the degrees in the left-hand column and the minutes at the top, and the lead will be found opposite the number of degrees, under the column headed by the given minutes. To find the lead for a given angle of spiral, with a line at right angles to the axis of the work, read the degrees in the right-hand column and the minutes at the bottom.

TABLE GIVING LEAD OF SPIRAL FOR GIVEN ANGLE—II

| Deg. | 0' | 6' | 12' | 18' | 24' | 30' | 36' | 42' | 48' | 54' | 60' | |
|---------------------------------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|------|
| <i>L</i> = lead for diameter 1. | | | | | | | | | | | | |
| 45 | 3.142 | 3.131 | 3.120 | 3.109 | 3.098 | 3.087 | 3.076 | 3.066 | 3.055 | 3.044 | 3.034 | 44 |
| 46 | 3.034 | 3.023 | 3.013 | 3.002 | 2.992 | 2.981 | 2.971 | 2.960 | 2.950 | 2.940 | 2.930 | 43 |
| 47 | 2.930 | 2.919 | 2.909 | 2.899 | 2.889 | 2.879 | 2.869 | 2.859 | 2.849 | 2.839 | 2.829 | 42 |
| 48 | 2.829 | 2.819 | 2.809 | 2.799 | 2.789 | 2.779 | 2.770 | 2.760 | 2.750 | 2.741 | 2.731 | 41 |
| 49 | 2.731 | 2.721 | 2.712 | 2.702 | 2.693 | 2.683 | 2.674 | 2.664 | 2.655 | 2.645 | 2.636 | 40 |
| 50 | 2.636 | 2.627 | 2.617 | 2.608 | 2.599 | 2.590 | 2.581 | 2.571 | 2.562 | 2.553 | 2.544 | 39 |
| 51 | 2.544 | 2.535 | 2.526 | 2.517 | 2.508 | 2.499 | 2.490 | 2.481 | 2.472 | 2.463 | 2.454 | 38 |
| 52 | 2.454 | 2.446 | 2.437 | 2.428 | 2.419 | 2.411 | 2.402 | 2.393 | 2.385 | 2.376 | 2.367 | 37 |
| 53 | 2.367 | 2.359 | 2.350 | 2.342 | 2.333 | 2.325 | 2.316 | 2.308 | 2.299 | 2.291 | 2.282 | 36 |
| 54 | 2.282 | 2.274 | 2.266 | 2.257 | 2.249 | 2.241 | 2.233 | 2.224 | 2.216 | 2.208 | 2.200 | 35 |
| 55 | 2.200 | 2.192 | 2.183 | 2.175 | 2.167 | 2.159 | 2.151 | 2.143 | 2.135 | 2.127 | 2.119 | 34 |
| 56 | 2.119 | 2.111 | 2.103 | 2.095 | 2.087 | 2.079 | 2.072 | 2.064 | 2.056 | 2.048 | 2.040 | 33 |
| 57 | 2.040 | 2.032 | 2.025 | 2.017 | 2.009 | 2.001 | 1.994 | 1.986 | 1.978 | 1.971 | 1.963 | 32 |
| 58 | 1.963 | 1.955 | 1.948 | 1.940 | 1.933 | 1.925 | 1.918 | 1.910 | 1.903 | 1.895 | 1.888 | 31 |
| 59 | 1.888 | 1.880 | 1.873 | 1.865 | 1.858 | 1.851 | 1.843 | 1.836 | 1.828 | 1.821 | 1.814 | 30 |
| 60 | 1.814 | 1.806 | 1.799 | 1.792 | 1.785 | 1.777 | 1.770 | 1.763 | 1.756 | 1.749 | 1.741 | 29 |
| 61 | 1.741 | 1.734 | 1.727 | 1.720 | 1.713 | 1.706 | 1.699 | 1.692 | 1.685 | 1.677 | 1.670 | 28 |
| 62 | 1.670 | 1.663 | 1.656 | 1.649 | 1.642 | 1.635 | 1.628 | 1.621 | 1.615 | 1.608 | 1.601 | 27 |
| 63 | 1.601 | 1.594 | 1.587 | 1.580 | 1.573 | 1.566 | 1.559 | 1.553 | 1.546 | 1.539 | 1.532 | 26 |
| 64 | 1.532 | 1.525 | 1.519 | 1.512 | 1.505 | 1.498 | 1.492 | 1.485 | 1.478 | 1.472 | 1.465 | 25 |
| 65 | 1.465 | 1.458 | 1.452 | 1.445 | 1.438 | 1.432 | 1.425 | 1.418 | 1.412 | 1.405 | 1.399 | 24 |
| 66 | 1.399 | 1.392 | 1.386 | 1.379 | 1.372 | 1.366 | 1.359 | 1.353 | 1.346 | 1.340 | 1.334 | 23 |
| 67 | 1.334 | 1.327 | 1.321 | 1.314 | 1.308 | 1.301 | 1.295 | 1.288 | 1.282 | 1.276 | 1.269 | 22 |
| 68 | 1.269 | 1.263 | 1.257 | 1.250 | 1.244 | 1.237 | 1.231 | 1.225 | 1.219 | 1.212 | 1.206 | 21 |
| 69 | 1.206 | 1.200 | 1.193 | 1.187 | 1.181 | 1.175 | 1.168 | 1.162 | 1.156 | 1.150 | 1.143 | 20 |
| 70 | 1.143 | 1.137 | 1.131 | 1.125 | 1.119 | 1.112 | 1.106 | 1.100 | 1.094 | 1.088 | 1.082 | 19 |
| 71 | 1.082 | 1.076 | 1.069 | 1.063 | 1.057 | 1.051 | 1.045 | 1.039 | 1.033 | 1.027 | 1.021 | 18 |
| 72 | 1.021 | 1.015 | 1.009 | 1.003 | 0.997 | 0.991 | 0.985 | 0.978 | 0.972 | 0.966 | 0.960 | 17 |
| 73 | 0.960 | 0.954 | 0.948 | 0.943 | 0.937 | 0.931 | 0.925 | 0.919 | 0.913 | 0.907 | 0.901 | 16 |
| 74 | 0.901 | 0.895 | 0.889 | 0.883 | 0.877 | 0.871 | 0.865 | 0.859 | 0.854 | 0.848 | 0.842 | 15 |
| 75 | 0.842 | 0.836 | 0.830 | 0.824 | 0.818 | 0.812 | 0.807 | 0.801 | 0.795 | 0.789 | 0.783 | 14 |
| 76 | 0.783 | 0.777 | 0.772 | 0.766 | 0.760 | 0.754 | 0.748 | 0.743 | 0.737 | 0.731 | 0.725 | 13 |
| 77 | 0.725 | 0.720 | 0.714 | 0.708 | 0.702 | 0.696 | 0.691 | 0.685 | 0.679 | 0.673 | 0.668 | 12 |
| 78 | 0.668 | 0.662 | 0.656 | 0.651 | 0.645 | 0.639 | 0.633 | 0.628 | 0.622 | 0.616 | 0.611 | 11 |
| 79 | 0.611 | 0.605 | 0.599 | 0.594 | 0.588 | 0.582 | 0.577 | 0.571 | 0.565 | 0.560 | 0.554 | 10 |
| 80 | 0.554 | 0.548 | 0.543 | 0.537 | 0.531 | 0.526 | 0.520 | 0.514 | 0.509 | 0.503 | 0.498 | 9 |
| 81 | 0.498 | 0.492 | 0.486 | 0.481 | 0.475 | 0.469 | 0.464 | 0.458 | 0.453 | 0.447 | 0.441 | 8 |
| 82 | 0.441 | 0.436 | 0.430 | 0.425 | 0.419 | 0.414 | 0.408 | 0.402 | 0.397 | 0.391 | 0.386 | 7 |
| 83 | 0.386 | 0.380 | 0.375 | 0.369 | 0.363 | 0.358 | 0.352 | 0.347 | 0.341 | 0.336 | 0.330 | 6 |
| 84 | 0.330 | 0.325 | 0.319 | 0.314 | 0.308 | 0.302 | 0.297 | 0.291 | 0.286 | 0.280 | 0.275 | 5 |
| 85 | 0.275 | 0.269 | 0.264 | 0.258 | 0.253 | 0.247 | 0.242 | 0.236 | 0.231 | 0.225 | 0.220 | 4 |
| 86 | 0.220 | 0.214 | 0.209 | 0.203 | 0.198 | 0.192 | 0.187 | 0.181 | 0.176 | 0.170 | 0.165 | 3 |
| 87 | 0.165 | 0.159 | 0.154 | 0.148 | 0.143 | 0.137 | 0.132 | 0.126 | 0.121 | 0.115 | 0.110 | 2 |
| 88 | 0.110 | 0.104 | 0.099 | 0.093 | 0.088 | 0.082 | 0.077 | 0.071 | 0.066 | 0.060 | 0.055 | 1 |
| 89 | 0.055 | 0.049 | 0.044 | 0.038 | 0.033 | 0.027 | 0.022 | 0.016 | 0.011 | 0.005 | 0.000 | 0 |
| | 60' | 54' | 48' | 42' | 36' | 30' | 24' | 18' | 12' | 6' | 0' | Deg. |

$$\text{Lead} = \frac{\pi}{\tan \alpha}$$

Table gives lead *L* for a diameter = 1.

For other diameters, if angle and diameter are given, lead = *L* × diameter
if angle and lead are given, diameter = lead ÷ *L*

If diameter and lead are given, *L* = lead ÷ diameter, and the angle corresponding to *L* is found in the table.

CONSTANTS FOR CALCULATING SPIRAL GEARS—1

| Gear | C_t = center distance per tooth of pinion, * | | | | | | | | | | | | | | | |
|-------------|--|--------|---------|---------|---------|---------|---------|--------|--------|--------|--------|--------|--------|--------|--------|--------|
| | L | 14.780 | 13.6077 | 12.6002 | 11.7246 | 10.9560 | 10.2757 | 9.6688 | 9.1238 | 8.6315 | 8.1841 | 7.7757 | 7.4011 | 7.0561 | 6.7372 | 6.4412 |
| Speed Ratio | F | 1.07 | 1.08 | 1.09 | 1.11 | 1.12 | 1.14 | 1.16 | 1.18 | 1.20 | 1.23 | 1.25 | 1.28 | 1.31 | 1.34 | 1.37 |
| | U | 1.0223 | 1.0263 | 1.0306 | 1.0353 | 1.0403 | 1.0457 | 1.0515 | 1.0576 | 1.0642 | 1.0711 | 1.0785 | 1.0864 | 1.0946 | 1.1034 | 1.1126 |
| Pinion | A | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 |
| | L | 7.5166 | 7.3543 | 7.2199 | 7.1033 | 7.0156 | 6.9385 | 6.8754 | 6.8240 | 6.7830 | 6.7511 | 6.7275 | 6.7115 | 6.7025 | 6.6999 | 6.7036 |
| Pinion | U | 7.0054 | 6.8412 | 6.7047 | 6.5907 | 6.4954 | 6.4157 | 6.3497 | 6.2951 | 6.2509 | 6.2155 | 6.1882 | 6.1683 | 6.1552 | 6.1482 | 6.1473 |
| | F | 11.0 | 87.9 | 70.6 | 57.8 | 47.8 | 40.0 | 33.9 | 28.9 | 25.0 | 21.7 | 19.1 | 16.8 | 14.9 | 13.3 | 11.9 |
| Pinion | L | 0.6678 | 0.7253 | 0.7933 | 0.8418 | 0.9008 | 0.9605 | 1.0208 | 1.0817 | 1.1434 | 1.2059 | 1.2693 | 1.3335 | 1.3987 | 1.4649 | 1.5322 |
| | A | 78 | 77 | 76 | 75 | 74 | 73 | 72 | 71 | 70 | 69 | 68 | 67 | 66 | 65 | 64 |
| Pinion | U | 4.8037 | 4.4454 | 4.1336 | 3.8637 | 3.6280 | 3.4203 | 3.2361 | 3.0715 | 2.9238 | 2.7904 | 2.6695 | 2.5593 | 2.4596 | 2.3662 | 2.2812 |
| | F | 11.0 | 87.9 | 70.6 | 57.8 | 47.8 | 40.0 | 33.9 | 28.9 | 25.0 | 21.7 | 19.1 | 16.8 | 14.9 | 13.3 | 11.9 |
| Pinion | L | 0.6678 | 0.7253 | 0.7933 | 0.8418 | 0.9008 | 0.9605 | 1.0208 | 1.0817 | 1.1434 | 1.2059 | 1.2693 | 1.3335 | 1.3987 | 1.4649 | 1.5322 |
| | A | 78 | 77 | 76 | 75 | 74 | 73 | 72 | 71 | 70 | 69 | 68 | 67 | 66 | 65 | 64 |

* Factors C_t do not apply for shafts at other than right angles.

A = angle of tooth helix, U = unit diameter per tooth, F = cutter factor, L = lead of spiral per inch pitch diameter, P_d = diametral pitch, D = pitch diameter, N = number of teeth (in either gear), N_a = number of teeth in pinion, C = center distance, C_t = center distance per tooth of pinion (1 diametral pitch).

$\frac{U \times N}{P_d} = D$; $N_a \frac{C_t}{P_d} = C$; $L \times D =$ lead of helix; $F \times N =$ number of teeth for which to select cutter.

(Explanatory notes continued in Table II).

CONSTANTS FOR CALCULATING SPIRAL GEARS—II

| Gear | Gt = center distance per tooth of pinion.* | | | | | | | | | | | | | | | | | | |
|-------------|--|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--|
| | L | 5.6676 | 5.4414 | 5.2282 | 5.0270 | 4.8376 | 4.6570 | 4.4867 | 4.3240 | 4.1690 | 4.0211 | 3.8795 | 3.7439 | 3.6139 | 3.4891 | 3.3689 | 3.2532 | 3.1416 | |
| F | 1.49 | 1.54 | 1.59 | 1.64 | 1.69 | 1.75 | 1.81 | 1.88 | 1.96 | 2.04 | 2.13 | 2.23 | 2.33 | 2.44 | 2.56 | 2.69 | 2.83 | | |
| U | 1.1433 | 1.1547 | 1.1666 | 1.1792 | 1.1924 | 1.2062 | 1.2208 | 1.2361 | 1.2521 | 1.2690 | 1.2868 | 1.3054 | 1.3250 | 1.3456 | 1.3673 | 1.3902 | 1.4142 | | |
| A | 29 | 30 | 31 | 32 | 33 | 34 | 35 | 36 | 37 | 38 | 39 | 40 | 41 | 42 | 43 | 44 | 45 | | |
| Speed Ratio | | | | | | | | | | | | | | | | | | | |
| 1 to 10 | 0.7481 | 6.7738 | 6.8040 | 6.8395 | 6.8799 | 6.9252 | 6.9755 | 7.0311 | 7.0916 | 7.1573 | 7.2283 | 7.3050 | 7.3872 | 7.4755 | 7.5699 | 7.6706 | 7.7782 | | |
| 1 to 9 | 0.1764 | 6.1964 | 6.2207 | 6.2499 | 6.2837 | 6.3221 | 6.3651 | 6.4131 | 6.4655 | 6.5228 | 6.5849 | 6.6522 | 6.7247 | 6.8027 | 6.8862 | 6.9755 | 7.0711 | | |
| 1 to 8 | 5.6048 | 5.6190 | 5.6373 | 5.6603 | 5.6875 | 5.7190 | 5.7547 | 5.7950 | 5.8394 | 5.8882 | 5.9415 | 5.9995 | 6.0622 | 6.1298 | 6.2025 | 6.2805 | 6.3640 | | |
| 1 to 7 | 5.0331 | 5.0416 | 5.0540 | 5.0707 | 5.0914 | 5.1159 | 5.1444 | 5.1770 | 5.2133 | 5.2537 | 5.2981 | 5.3468 | 5.3997 | 5.4570 | 5.5189 | 5.5854 | 5.6569 | | |
| 1 to 6 | 4.4614 | 4.4643 | 4.4707 | 4.4811 | 4.4952 | 4.5128 | 4.5340 | 4.5589 | 4.5873 | 5.6192 | 5.6548 | 5.6941 | 5.7372 | 5.7842 | 5.8352 | 5.8903 | 5.9497 | | |
| 1 to 5 | 3.8897 | 3.8869 | 3.8874 | 3.8915 | 3.8990 | 3.9097 | 3.9236 | 3.9409 | 3.9612 | 3.9847 | 4.0114 | 4.0414 | 4.0747 | 4.1114 | 4.1515 | 4.1952 | 4.2426 | | |
| 2 to 9 | 3.6039 | 3.5982 | 3.5958 | 3.5967 | 3.6009 | 3.6081 | 3.6184 | 3.6319 | 3.6482 | 3.6675 | 3.6897 | 3.7151 | 3.7434 | 3.7750 | 3.8097 | 3.8477 | 3.8891 | | |
| 1 to 4 | 3.3181 | 3.3095 | 3.3041 | 3.3019 | 3.3028 | 3.3060 | 3.3132 | 3.3228 | 3.3351 | 3.3502 | 3.3680 | 3.3887 | 3.4121 | 3.4385 | 3.4678 | 3.5001 | 3.5355 | | |
| 2 to 7 | 3.0322 | 3.0208 | 3.0124 | 3.0071 | 3.0047 | 3.0050 | 3.0081 | 3.0138 | 3.0221 | 3.0330 | 3.0463 | 3.0624 | 3.0809 | 3.1022 | 3.1260 | 3.1526 | 3.1820 | | |
| 3 to 10 | 2.9370 | 2.9246 | 2.9152 | 2.9089 | 2.9054 | 2.9045 | 2.9063 | 2.9108 | 2.9177 | 2.9272 | 2.9391 | 2.9536 | 2.9705 | 2.9900 | 3.0121 | 3.0368 | 3.0641 | | |
| 1 to 3 | 2.7464 | 2.7321 | 2.7208 | 2.7123 | 2.7066 | 2.7035 | 2.7029 | 2.7048 | 2.7090 | 2.7157 | 2.7246 | 2.7360 | 2.7496 | 2.7657 | 2.7842 | 2.8051 | 2.8284 | | |
| 3 to 8 | 2.5558 | 2.5397 | 2.5263 | 2.5158 | 2.5079 | 2.5024 | 2.4994 | 2.4988 | 2.5004 | 2.5042 | 2.5102 | 2.5184 | 2.5288 | 2.5415 | 2.5563 | 2.5734 | 2.5927 | | |
| 2 to 5 | 2.4606 | 2.4435 | 2.4291 | 2.4176 | 2.4085 | 2.4019 | 2.3977 | 2.3958 | 2.3960 | 2.3985 | 2.4030 | 2.4097 | 2.4184 | 2.4293 | 2.4424 | 2.4575 | 2.4749 | | |
| 3 to 7 | 2.3653 | 2.3472 | 2.3319 | 2.3193 | 2.3092 | 2.3014 | 2.2959 | 2.2928 | 2.2917 | 2.2927 | 2.2957 | 2.3009 | 2.3080 | 2.3172 | 2.3284 | 2.3417 | 2.3570 | | |
| 4 to 9 | 2.2776 | 2.2591 | 2.2433 | 2.2272 | 2.2104 | 2.1925 | 2.1747 | 2.1568 | 2.1374 | 2.1227 | 2.1104 | 2.1004 | 2.0925 | 2.0868 | 2.0833 | 2.0871 | 2.0929 | 2.1005 | |
| 1 to 2 | 2.1747 | 2.1548 | 2.1374 | 2.1227 | 2.1104 | 2.1004 | 2.0925 | 2.0868 | 2.0830 | 2.0812 | 2.0813 | 2.0833 | 2.0871 | 2.0929 | 2.1005 | 2.1100 | 2.1213 | | |
| Pinion | A | 61 | 60 | 59 | 58 | 57 | 56 | 55 | 54 | 53 | 52 | 51 | 50 | 49 | 48 | 47 | 46 | 45 | |
| U | 2.0627 | 2.0000 | 1.9416 | 1.8871 | 1.8361 | 1.7883 | 1.7434 | 1.7013 | 1.6616 | 1.6243 | 1.5890 | 1.5557 | 1.5242 | 1.4945 | 1.4663 | 1.4396 | 1.4142 | | |
| F | 6.79 | 8.00 | 7.31 | 6.72 | 6.18 | 5.72 | 5.30 | 4.93 | 4.59 | 4.29 | 4.01 | 3.77 | 3.54 | 3.34 | 3.15 | 2.98 | 2.83 | | |
| L | 1.7414 | 1.8138 | 1.8877 | 1.9631 | 2.0402 | 2.1190 | 2.1997 | 2.2825 | 2.3673 | 2.4545 | 2.5440 | 2.6361 | 2.7302 | 2.8267 | 2.9256 | 3.0268 | 3.1308 | 3.1416 | |

* Factors Gt do not apply for shafts at other than right angles.

Example of use of tables:— Required number of teeth, diameters, and center distance for a pair of gears; helix angle of pinion, 60 degrees; of gear, 30 degrees; speed ratio 2 to 5; 6 diametral pitch. From table, $G_t = 2.4435$, and by formula $N_a \frac{G_t}{G_p}$, disregarding for the moment the number of teeth we have $\frac{2.4435}{\frac{6}{2}} = 0.40725$. Assume a required center distance of approximately 5 inches; make $N_a = 12$; then $0.40725 \times 12 = 4.887 = G_p$; $12 \times \frac{6}{5} = 30 =$ teeth in gear. $\frac{G_t}{N_a G_p} = \frac{2.4435}{12 \times 30} = 0.00675$ inches = pitch diameter of pinion. $L \times D = 1.814 \times 4 = 7.256 =$ lead of spiral of pinion. $F \times N = 8 \times 12 = 96 =$ number of teeth for which cutter should be selected. The same formulas are used for finding the pitch diameter, lead and cutter for gear. (Explanatory notes continued in Table III).

Contributed by C. W. Pitman, Machinery's Data Sheet No. 106. Explanatory note: Page 31.

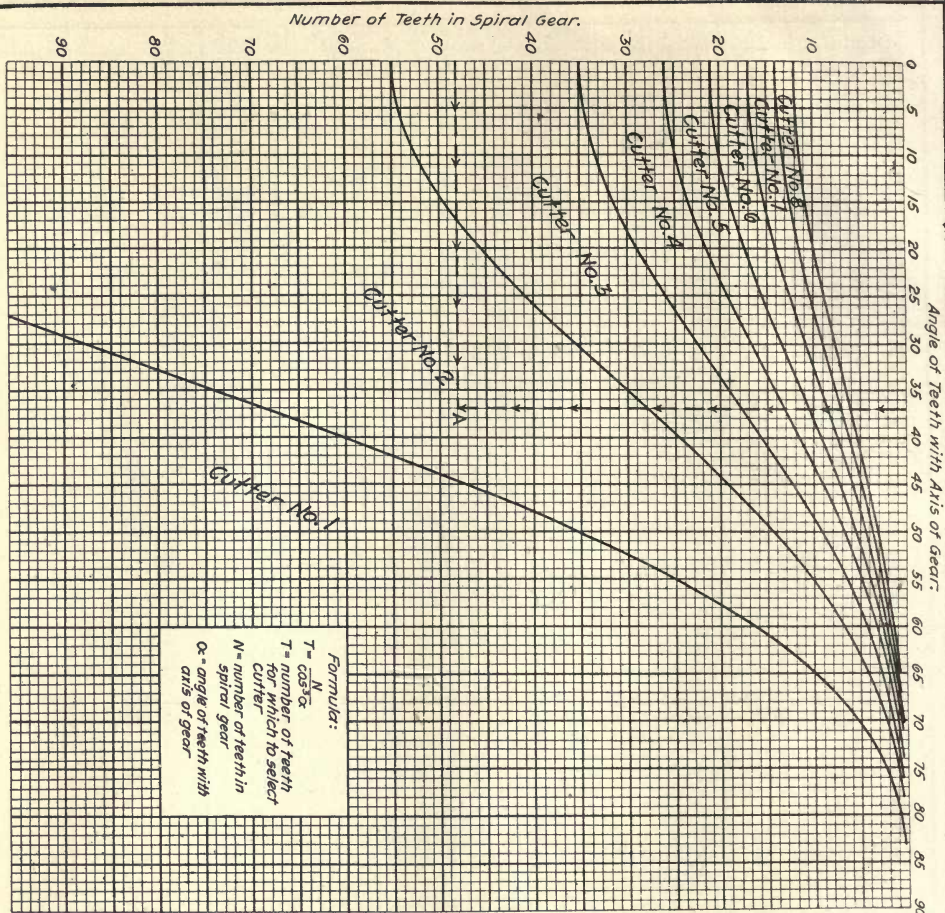
CONSTANTS FOR CALCULATING SPIRAL GEARS—IV

| Gear | $C_g = \text{center distance per tooth of pinion.}^*$ | | | | | | | | | | | | | | | |
|-------------|---|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|
| | L | 5.6676 | 5.4414 | 5.2282 | 5.0276 | 4.8376 | 4.6576 | 4.4867 | 4.3240 | 4.1690 | 4.0211 | 3.8795 | 3.7439 | 3.6139 | 3.4891 | 3.3689 |
| Speed Ratio | F | 1.49 | 1.54 | 1.59 | 1.64 | 1.69 | 1.75 | 1.81 | 1.88 | 1.96 | 2.04 | 2.13 | 2.23 | 2.33 | 2.44 | 2.56 |
| | U | 1.433 | 1.1547 | 1.1666 | 1.1792 | 1.1924 | 1.2062 | 1.2208 | 1.2361 | 1.2521 | 1.2690 | 1.2868 | 1.3054 | 1.3250 | 1.3456 | 1.3673 |
| Pinion | A | 29 | 30 | 31 | 32 | 33 | 34 | 35 | 36 | 37 | 38 | 39 | 40 | 41 | 42 | 43 |
| | L | 1.7414 | 1.8138 | 1.8877 | 1.9631 | 2.0402 | 2.1190 | 2.1997 | 2.2825 | 2.3673 | 2.4545 | 2.5440 | 2.6361 | 2.7302 | 2.8267 | 2.9260 |
| Pinion | A | 61 | 60 | 59 | 58 | 57 | 56 | 55 | 54 | 53 | 52 | 51 | 50 | 49 | 48 | 47 |
| | F | 2.0627 | 2.0000 | 1.9416 | 1.8871 | 1.8361 | 1.7883 | 1.7434 | 1.7013 | 1.6616 | 1.6243 | 1.5890 | 1.5557 | 1.5242 | 1.4945 | 1.4663 |
| Pinion | U | 1.7414 | 1.8138 | 1.8877 | 1.9631 | 2.0402 | 2.1190 | 2.1997 | 2.2825 | 2.3673 | 2.4545 | 2.5440 | 2.6361 | 2.7302 | 2.8267 | 2.9260 |
| | L | 1.7414 | 1.8138 | 1.8877 | 1.9631 | 2.0402 | 2.1190 | 2.1997 | 2.2825 | 2.3673 | 2.4545 | 2.5440 | 2.6361 | 2.7302 | 2.8267 | 2.9260 |

* Factors C_g do not apply for shafts at other than right angles.

Example: Parallel shafts, speed ratio 1 to 5, helix angle 15 degrees; 8 diametral pitch. Assume 14 and 70 teeth for pinion and gear, respectively. $\frac{U \times N_g}{U \times N_p} = D$; $\frac{1.0353 \times 14}{8} = 1.812$ inch, diameter of pinion; $\frac{1.0353 \times 70}{8} = 9.059$ inches, diameter of gear; $C = \frac{1.812 + 9.059}{2} = 5.436$ inches.

DIAGRAM FOR FINDING SPIRAL GEAR CUTTER NUMBERS

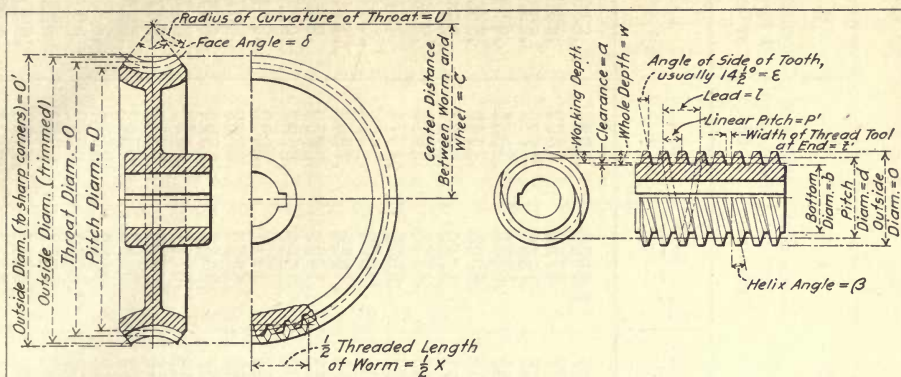


The cutters used for milling spiral or helical gears are standard spur gear cutters, the number of a cutter and its pitch for a given case being defined by the angle (with axis) and normal pitch. This diagram gives the numbers of the cutters only, the pitch having been previously determined.

The selection of the cutter is fixed by the formula given in the lower right-hand corner of the diagram. The delimiting curves thereon were plotted by the formula, the area between the curves being the field of intersection of the combinations of angles and numbers of teeth covered by each designated cutter number.

For example, suppose the angle of the teeth of a gear is 37 degrees with its axis, and the number of teeth is 48. The point A, at which the horizontal line (representing the tooth number), and the vertical line (representing the angle) intersect, falls within the area marked "Cutter No. 2." Therefore, a No. 2 cutter is required to cut a 48-tooth spiral gear having the teeth at an angle of 37 degrees with its axis.

RULES AND FORMULAS FOR WORM GEARING CALCULATIONS



| No. | To Find | Rule | Formula |
|-----|--|---|---|
| 1 | Linear Pitch | Divide the lead by the number of threads. — It is understood, of course, that by the number of threads is meant, not the number of threads per inch, but the number of threads in the whole worm—one, if it is single-threaded, four, if it is quadruple-threaded, etc. | $P' = \frac{l}{n}$ |
| 2 | Addendum of Worm Tooth | Multiply the linear pitch by 0.3183. | $s = 0.3183 P'$ |
| 3 | Pitch Diam. of Worm | Subtract twice the addendum from the outside diameter. | $d = O - 2s$ |
| 4 | Pitch Diam. of Worm-Wheel | Multiply the number of teeth in the wheel by the linear pitch of the worm, and divide the product by 3.1416. | $D = \frac{NP'}{3.1416}$ |
| 5 | Center Distance between Worm and Gear | Add together the pitch diameter of the worm and the pitch diameter of the worm-wheel, and divide the sum by 2. | $C = \frac{d + D}{2}$ |
| 6 | Whole Depth of Worm Tooth | Multiply the linear pitch by 0.6866. | $w = 0.6866 P'$ |
| 7 | Bottom Diam. of Worm | Subtract twice the whole depth of tooth from the outside diameter. | $b = O - 2w$ |
| 8 | Helix Angle of Worm | Multiply the pitch diameter of the worm by 3.1416, and divide the product by the lead; the quotient is the cotangent of the tooth angle of the worm. | $\cot \beta = \frac{3.1416 d}{l}$ |
| 9 | Width of Thread Tool at End | Multiply the linear pitch by 0.31. | $z' = 0.31 P'$ |
| 10 | Throat Diam. of Worm-Wheel | Add twice the addendum of the worm tooth to the pitch diameter of the worm-wheel. | $O = D + 2s$ |
| 11 | Radius of Worm-Wheel Throat | Subtract twice the addendum of the worm tooth from half the outside diameter of the worm. | $U = \frac{O}{2} - 2s$ |
| 12 | Diam. of Worm-Wheel to Sharp Corners | Multiply the throat radius by the cosine of half the face angle, subtract this quantity from the throat radius, multiply the remainder by 2, and add the product to the throat diameter of the worm-wheel. | $O' = 2 \left(U - U \cos \frac{\delta}{2} \right) + O$ |
| 13 | Minimum Length of Worm for Complete Action | Subtract four times the addendum of the worm thread from the throat diameter of the wheel, square the remainder, and subtract the result from the square of the throat diameter of the wheel. The square root of the result is the minimum length of worm advisable. | $X = \sqrt{O^2 - (O - 4s)^2}$ |
| 14 | Outside Diam. of Worm | Add together the pitch diameter and twice the addendum. | $O = d + 2s$ |
| 15 | Pitch Diam. of Worm | Subtract the pitch diameter of the worm-wheel from twice the center distance. | $d = 2C - D$ |

WORMS AND WORM GEARING.

| C. P. | N | D. P. | H | D | C | S | W. D. | T | W | B |
|------------------|-----------------------|-----------------------------|-------------------------|--------------------------------|--|----------------------------------|-----------------------|-----------------------------------|------------------------------|--------------------------|
| Circular Pitch. | Threads per Inch. | Diametral Pitch. | Tooth above Pitch Line. | Working Depth of Tooth. | Clearance. | Depth of Space below Pitch Line. | Whole Depth of Tooth. | Thickness of Tooth on Pitch Line. | Width of Thread Tool at End. | Width of Thread at Top. |
| C. P. Inches. | $N = \frac{1}{C. P.}$ | $D. P. = \frac{\pi}{C. P.}$ | $H = \frac{1}{D. P.}$ | $D = 2 \times \frac{1}{D. P.}$ | $C = \frac{1}{2} \times \frac{1}{D. P.}$ | $S = H + C$ | $W. D. = D + C$ | $T = \frac{C. P.}{2}$ | $W = .3148 \times C. P.$ | $B = .3854 \times C. P.$ |
| 2 | 1-2 | 1.5708 | .6366 | 1.2732 | .0795 | .7161 | 1.3527 | 1.0000 | .6296 | .6708 |
| 1½ | 4-7 | 1.7952 | .5570 | 1.1141 | .0696 | .6266 | 1.1837 | .8750 | .5509 | .5869 |
| 1¼ | 2-3 | 2.0944 | .4775 | .9549 | .0596 | .5371 | 1.0145 | .7500 | .4722 | .5031 |
| 1¼ | 4-5 | 2.5133 | .3979 | .7958 | .0497 | .4476 | .8455 | .6250 | .3935 | .4192 |
| 1 | 1 | 3.1416 | .3183 | .6366 | .0397 | .3580 | .6763 | .5000 | .3148 | .3354 |
| ¾ | 1½ | 4.1888 | .2387 | .4775 | .0298 | .2685 | .5073 | .3750 | .2361 | .2515 |
| 2-3 | 1½ | 4.7124 | .2122 | .4244 | .0265 | .2387 | .4509 | .3333 | .2098 | .2236 |
| 1-2 | 2 | 6.2832 | .1592 | .3183 | .0199 | .1791 | .3382 | .2500 | .1574 | .1677 |
| 2-5 | 2½ | 7.8540 | .1273 | .2546 | .0159 | .1432 | .2705 | .2000 | .1259 | .1341 |
| 1-3 | 3 | 9.4248 | .1061 | .2122 | .0132 | .1193 | .2254 | .1666 | .1049 | .1118 |
| 2-7 | 3½ | 10.9956 | .0909 | .1819 | .0113 | .1022 | .1932 | .1429 | .0899 | .0958 |
| 1-4 | 4 | 12.5664 | .0796 | .1591 | .0099 | .0895 | .1690 | .1250 | .0787 | .0838 |
| 2-9 | 4½ | 14.1372 | .0707 | .1415 | .0088 | .0795 | .1503 | .1111 | .0699 | .0745 |
| 1-5 | 5 | 15.7080 | .0637 | .1273 | .0079 | .0716 | .1352 | .1000 | .0629 | .0670 |
| 1-6 | 6 | 18.8496 | .0531 | .1061 | .0066 | .0597 | .1127 | .0833 | .0524 | .0559 |
| 1-7 | 7 | 21.9911 | .0455 | .0910 | .0056 | .0511 | .0966 | .0714 | .0449 | .0479 |
| 1-8 | 8 | 25.1327 | .0398 | .0796 | .0049 | .0447 | .0845 | .0625 | .0393 | .0419 |
| 1-9 | 9 | 28.2743 | .0354 | .0707 | .0044 | .0398 | .0752 | .0555 | .0349 | .0372 |
| 1-10 | 10 | 31.4159 | .0318 | .0637 | .0039 | .0357 | .0676 | .0500 | .0314 | .0335 |
| 1-12 | 12 | 37.6992 | .0265 | .0530 | .0033 | .0298 | .0563 | .0416 | .0262 | .0279 |
| 1-14 | 14 | 43.9824 | .0227 | .0454 | .0028 | .0255 | .0482 | .0357 | .0224 | .0239 |
| 1-16 | 16 | 50.2655 | .0199 | .0398 | .0024 | .0223 | .0422 | .0312 | .0196 | .0209 |
| 1-18 | 18 | 56.5488 | .0176 | .0352 | .0022 | .0198 | .0374 | .0277 | .0174 | .0186 |

eter. Referring to the diagram for values of a , page 12, follow a line close to the 57-degree pitch angle line, until it intersects the curve for $2P$. Follow from this point the line horizontally to the left where a is found to equal 0.270 inch. The outside diameter will be the sum of the pitch diameter, 20 inches, and $2a$, or 20.54 inches. Dimension b may be found from the same diagram in the same manner, except that the complement of the pitch angle must be used as the starting point. The complement angle of 56 degrees 59 minutes is 33 degrees 1 minute, and in the same way as above described we find that $b = 0.420$ inch.

For finding the angle of increment we follow the line corresponding to 56 degrees 59 minutes on the diagram on page 13 to the intersecting point with the line radiating from zero, and marked 40 teeth. By transferring this point horizontally over to the scale for the angles of increment at the left, we find that this angle in this case equals 2 degrees 23 minutes, the units of the minutes being estimated. This angle added to the pitch angle of 56 degrees 59 minutes gives a face angle of 59 degrees 22 minutes. [MACHINERY, May, 1907, Bevel Gear Diagrams.]

Outside Diameter of Bevel Gears

On pages 14 and 15 are given two tables for determining the outside diameter of bevel gears. The explanation on page 14 gives full instructions for the use of these tables as well as a concrete working example. This short-hand method for finding the outside diameters of bevel gears and pinions will be found convenient in many cases, and saves a considerable amount of calculation, at the same time as mistakes are less likely to occur.

Rules and Formulas for Spiral Gearing

The terms "spiral" and "helical," in relation to gears, are used synonymously,

but only the latter expression is correct. However, the expression "spiral gear" is commonly used among mechanics in this connection. This term is, therefore, used in the following for denoting this class of gears.

The following definitions should be clearly understood in order to avoid misunderstandings. The center angle of a pair of spiral gears is the angle made by the two center lines or axes of the gears. The tooth angle is the angle which the direction of the tooth makes with the axis of the gear. The normal diametral pitch is the diametral pitch of the cutter used for cutting the teeth in a spiral gear.

On page 17 are given a set of rules and formulas for calculating spiral gearing. The notation used in the formulas is easily apparent by comparing the formulas with the corresponding rules. The numbers given in the left-hand column are only for convenience in referring to any specific rule. The rules and formulas are given in the same order as they would ordinarily be used by the designer when calculating a pair of spiral gears. The table is arranged similar to that for bevel gear dimensions on pages 4, 5 and 6. [MACHINERY'S Reference Series No. 20, Spiral Gearing, Chapter I.]

Lead of Spiral for Given Angle

On pages 18 and 19 are given two tables for finding the lead of spiral in inches when the spiral angle in degrees and minutes is given. The lead found in the table is for a diameter = 1, and for other diameters the lead equals the value found in the table multiplied by the diameter of the work. As an example, assume that it is required to find the lead corresponding to a spiral angle of 55 degrees and a diameter of 5 inches. From the table on page 19 we find that the lead for diameter 1 and 55 degrees 0 minutes equals 2.200. Multiplying this value by 5 we have $5 \times 2.200 = 11$

(Continued on page 31.)

WORM THREAD HELIX ANGLES—I

| Lead of Worm, Inches | Pitch Line Diameter of Worm, Inches. | | | | | | | | | | | | | | |
|----------------------|--------------------------------------|------------------|------------------|------------------|------------------|------------------|------------------|------------------|------------------|------------------|------------------|------------------|------------------|------------------|--|
| | 1 | 1 $\frac{1}{8}$ | 1 $\frac{1}{4}$ | 1 $\frac{3}{8}$ | 1 $\frac{1}{2}$ | 1 $\frac{5}{8}$ | 1 $\frac{3}{4}$ | 1 $\frac{7}{8}$ | 2 | 2 $\frac{1}{8}$ | 2 $\frac{1}{4}$ | 2 $\frac{3}{8}$ | 2 $\frac{1}{2}$ | 2 $\frac{5}{8}$ | |
| $\frac{1}{4}$ | 4 $\frac{1}{2}$ | 4 | 3 $\frac{1}{2}$ | 3 $\frac{3}{4}$ | 3 | 2 $\frac{3}{4}$ | 2 $\frac{1}{2}$ | 2 $\frac{1}{2}$ | 2 $\frac{1}{4}$ | 2 $\frac{1}{4}$ | 2 | 2 | 2 | 1 $\frac{3}{4}$ | |
| $\frac{3}{8}$ | 6 $\frac{3}{4}$ | 6 | 5 $\frac{1}{2}$ | 5 | 4 $\frac{1}{2}$ | 4 $\frac{1}{4}$ | 4 | 3 $\frac{3}{4}$ | 3 $\frac{1}{2}$ | 3 $\frac{1}{4}$ | 3 | 3 | 2 $\frac{3}{4}$ | 2 $\frac{1}{2}$ | |
| $\frac{1}{2}$ | 9 | 8 | 7 $\frac{1}{4}$ | 6 $\frac{3}{4}$ | 6 | 5 $\frac{1}{2}$ | 5 $\frac{1}{4}$ | 5 | 4 $\frac{1}{2}$ | 4 $\frac{1}{4}$ | 4 $\frac{1}{4}$ | 4 | 3 $\frac{3}{4}$ | 3 $\frac{1}{2}$ | |
| $\frac{5}{8}$ | 11 $\frac{1}{4}$ | 10 | 9 | 8 $\frac{1}{4}$ | 7 $\frac{1}{2}$ | 7 | 6 $\frac{1}{2}$ | 6 | 5 $\frac{3}{4}$ | 5 $\frac{1}{4}$ | 5 | 4 $\frac{3}{4}$ | 4 $\frac{1}{2}$ | 4 $\frac{1}{2}$ | |
| $\frac{3}{4}$ | 13 $\frac{1}{2}$ | 12 | 10 $\frac{3}{4}$ | 10 | 9 | 8 $\frac{1}{2}$ | 7 $\frac{3}{4}$ | 7 $\frac{1}{4}$ | 6 $\frac{3}{4}$ | 6 $\frac{1}{2}$ | 6 | 5 $\frac{3}{4}$ | 5 $\frac{1}{2}$ | 5 $\frac{1}{4}$ | |
| $\frac{7}{8}$ | 15 $\frac{1}{2}$ | 14 | 12 $\frac{1}{2}$ | 11 $\frac{1}{2}$ | 10 $\frac{1}{2}$ | 9 $\frac{3}{4}$ | 9 | 8 $\frac{1}{2}$ | 8 | 7 $\frac{1}{2}$ | 7 | 6 $\frac{3}{4}$ | 6 $\frac{1}{2}$ | 6 | |
| 1 | 17 $\frac{3}{4}$ | 16 | 14 $\frac{1}{4}$ | 13 | 12 | 11 $\frac{1}{4}$ | 10 $\frac{1}{4}$ | 9 $\frac{3}{4}$ | 9 | 8 $\frac{1}{2}$ | 8 | 7 $\frac{3}{4}$ | 7 $\frac{1}{4}$ | 7 | |
| 1 $\frac{1}{8}$ | 19 $\frac{3}{4}$ | 18 | 16 | 14 $\frac{3}{4}$ | 13 $\frac{1}{2}$ | 12 $\frac{1}{2}$ | 11 $\frac{1}{2}$ | 11 | 10 $\frac{1}{4}$ | 9 $\frac{1}{2}$ | 9 | 8 $\frac{1}{2}$ | 8 | 7 $\frac{3}{4}$ | |
| 1 $\frac{1}{4}$ | 21 $\frac{3}{4}$ | 19 $\frac{1}{2}$ | 17 $\frac{3}{4}$ | 16 $\frac{1}{4}$ | 15 | 13 $\frac{3}{4}$ | 12 $\frac{3}{4}$ | 12 | 11 $\frac{1}{4}$ | 10 $\frac{3}{4}$ | 10 | 9 $\frac{1}{2}$ | 9 | 8 $\frac{3}{4}$ | |
| 1 $\frac{3}{8}$ | 23 $\frac{3}{4}$ | 21 $\frac{1}{4}$ | 19 $\frac{1}{4}$ | 17 $\frac{3}{4}$ | 16 $\frac{1}{4}$ | 15 | 14 | 13 | 12 $\frac{1}{2}$ | 11 $\frac{3}{4}$ | 11 | 10 $\frac{1}{2}$ | 10 | 9 $\frac{1}{2}$ | |
| 1 $\frac{1}{2}$ | 25 $\frac{1}{2}$ | 23 | 21 | 19 $\frac{1}{4}$ | 17 $\frac{1}{2}$ | 16 $\frac{1}{2}$ | 15 $\frac{1}{4}$ | 14 $\frac{1}{4}$ | 13 $\frac{1}{2}$ | 12 $\frac{3}{4}$ | 12 | 11 $\frac{1}{2}$ | 11 | 10 $\frac{1}{4}$ | |
| 1 $\frac{5}{8}$ | 27 $\frac{1}{2}$ | 24 $\frac{3}{4}$ | 22 $\frac{1}{2}$ | 20 $\frac{3}{4}$ | 19 | 17 $\frac{3}{4}$ | 16 $\frac{1}{2}$ | 15 $\frac{1}{2}$ | 14 $\frac{1}{2}$ | 13 $\frac{3}{4}$ | 13 | 12 $\frac{1}{4}$ | 11 $\frac{3}{4}$ | 11 $\frac{1}{4}$ | |
| 1 $\frac{3}{4}$ | 29 $\frac{1}{4}$ | 26 $\frac{1}{2}$ | 24 | 22 | 20 $\frac{1}{2}$ | 19 | 17 $\frac{3}{4}$ | 16 $\frac{1}{2}$ | 15 $\frac{1}{2}$ | 14 $\frac{3}{4}$ | 14 | 13 $\frac{1}{4}$ | 12 $\frac{1}{2}$ | 12 | |
| 1 $\frac{7}{8}$ | 30 $\frac{3}{4}$ | 28 | 25 $\frac{1}{2}$ | 23 $\frac{1}{2}$ | 21 $\frac{3}{4}$ | 20 $\frac{1}{4}$ | 19 | 17 $\frac{1}{2}$ | 16 $\frac{3}{4}$ | 15 $\frac{3}{4}$ | 15 | 14 $\frac{1}{4}$ | 13 $\frac{1}{2}$ | 13 | |
| 2 | 32 $\frac{1}{2}$ | 29 $\frac{3}{4}$ | 27 | 25 | 23 | 21 $\frac{1}{2}$ | 20 | 19 | 17 $\frac{3}{4}$ | 16 $\frac{3}{4}$ | 15 $\frac{3}{4}$ | 15 | 14 $\frac{1}{4}$ | 13 $\frac{3}{4}$ | |
| 2 $\frac{1}{4}$ | 35 $\frac{3}{4}$ | 32 $\frac{3}{4}$ | 30 | 27 $\frac{1}{2}$ | 25 $\frac{1}{2}$ | 24 | 22 $\frac{1}{4}$ | 21 | 19 $\frac{3}{4}$ | 18 $\frac{3}{4}$ | 17 $\frac{3}{4}$ | 17 | 16 | 15 $\frac{1}{4}$ | |
| 2 $\frac{1}{2}$ | 38 $\frac{1}{2}$ | 35 $\frac{1}{2}$ | 32 $\frac{1}{2}$ | 30 | 28 | 26 $\frac{1}{4}$ | 24 $\frac{1}{2}$ | 23 | 21 $\frac{3}{4}$ | 20 $\frac{3}{4}$ | 19 $\frac{1}{2}$ | 18 $\frac{1}{2}$ | 17 $\frac{3}{4}$ | 17 | |
| 2 $\frac{3}{4}$ | 41 $\frac{1}{4}$ | 38 | 35 | 32 $\frac{1}{2}$ | 30 $\frac{1}{4}$ | 28 $\frac{1}{2}$ | 26 $\frac{1}{2}$ | 25 | 23 $\frac{3}{4}$ | 22 $\frac{1}{2}$ | 21 $\frac{1}{4}$ | 20 $\frac{1}{4}$ | 19 $\frac{1}{4}$ | 18 $\frac{1}{2}$ | |
| 3 | 43 $\frac{3}{4}$ | 40 $\frac{1}{2}$ | 37 $\frac{1}{2}$ | 35 | 32 $\frac{1}{2}$ | 30 $\frac{1}{2}$ | 28 $\frac{3}{4}$ | 27 | 25 $\frac{1}{2}$ | 24 $\frac{1}{4}$ | 23 | 22 | 21 | 20 | |
| 3 $\frac{1}{4}$ | 46 | 42 $\frac{3}{4}$ | 39 $\frac{3}{4}$ | 37 | 34 $\frac{1}{2}$ | 32 $\frac{1}{2}$ | 30 $\frac{3}{4}$ | 29 | 27 $\frac{1}{2}$ | 26 | 24 $\frac{1}{4}$ | 23 $\frac{1}{2}$ | 22 $\frac{1}{2}$ | 21 $\frac{1}{2}$ | |
| 3 $\frac{1}{2}$ | 48 $\frac{1}{4}$ | 45 | 41 $\frac{3}{4}$ | 39 $\frac{1}{4}$ | 36 $\frac{3}{4}$ | 34 $\frac{1}{2}$ | 32 $\frac{1}{2}$ | 30 $\frac{3}{4}$ | 29 $\frac{1}{4}$ | 27 $\frac{3}{4}$ | 26 $\frac{1}{4}$ | 25 $\frac{1}{4}$ | 24 | 23 | |
| 3 $\frac{3}{4}$ | 50 $\frac{1}{4}$ | 47 | 43 $\frac{3}{4}$ | 41 | 38 $\frac{3}{4}$ | 36 $\frac{1}{2}$ | 34 $\frac{1}{4}$ | 32 $\frac{1}{2}$ | 31 | 29 $\frac{1}{2}$ | 28 | 26 $\frac{3}{4}$ | 25 $\frac{1}{2}$ | 24 $\frac{1}{2}$ | |
| 4 | 51 $\frac{3}{4}$ | 48 $\frac{1}{2}$ | 45 $\frac{3}{4}$ | 43 | 40 $\frac{1}{2}$ | 38 $\frac{1}{4}$ | 36 | 34 $\frac{1}{4}$ | 32 $\frac{3}{4}$ | 31 | 29 $\frac{1}{2}$ | 28 $\frac{1}{4}$ | 27 | 26 | |
| 4 $\frac{1}{4}$ | 53 $\frac{1}{2}$ | 50 $\frac{1}{2}$ | 47 $\frac{1}{2}$ | 44 $\frac{3}{4}$ | 42 $\frac{1}{4}$ | 39 $\frac{3}{4}$ | 37 $\frac{3}{4}$ | 36 | 34 $\frac{1}{4}$ | 32 $\frac{1}{2}$ | 31 | 29 $\frac{3}{4}$ | 28 $\frac{1}{2}$ | 27 $\frac{1}{4}$ | |
| 4 $\frac{1}{2}$ | 55 | 52 | 49 | 46 $\frac{1}{2}$ | 43 $\frac{3}{4}$ | 41 $\frac{1}{2}$ | 39 $\frac{1}{2}$ | 37 $\frac{1}{2}$ | 35 $\frac{3}{4}$ | 34 | 32 $\frac{1}{2}$ | 31 $\frac{1}{4}$ | 30 | 28 $\frac{3}{4}$ | |
| 4 $\frac{3}{4}$ | 56 $\frac{1}{2}$ | 53 $\frac{1}{2}$ | 50 $\frac{1}{2}$ | 48 | 45 $\frac{1}{4}$ | 43 | 40 $\frac{3}{4}$ | 39 | 37 $\frac{1}{4}$ | 35 $\frac{1}{2}$ | 34 | 32 $\frac{1}{2}$ | 31 $\frac{1}{4}$ | 30 | |
| 5 | 57 $\frac{3}{4}$ | 54 $\frac{3}{4}$ | 51 $\frac{3}{4}$ | 49 $\frac{1}{4}$ | 46 $\frac{3}{4}$ | 44 $\frac{1}{2}$ | 42 $\frac{1}{4}$ | 40 $\frac{1}{2}$ | 38 $\frac{3}{4}$ | 37 | 35 $\frac{1}{4}$ | 34 | 32 $\frac{1}{2}$ | 31 $\frac{1}{4}$ | |
| 5 $\frac{1}{4}$ | 59 $\frac{1}{4}$ | 56 $\frac{1}{4}$ | 53 $\frac{1}{4}$ | 50 $\frac{3}{4}$ | 48 | 46 | 43 $\frac{3}{4}$ | 41 $\frac{3}{4}$ | 40 | 38 $\frac{1}{4}$ | 36 $\frac{1}{2}$ | 35 $\frac{1}{4}$ | 34 | 32 $\frac{1}{2}$ | |
| 5 $\frac{1}{2}$ | 60 $\frac{1}{4}$ | 57 $\frac{1}{4}$ | 54 $\frac{3}{4}$ | 52 | 49 $\frac{1}{2}$ | 47 $\frac{1}{4}$ | 45 | 43 | 41 $\frac{1}{4}$ | 39 $\frac{1}{2}$ | 38 | 36 $\frac{1}{2}$ | 35 | 33 $\frac{3}{4}$ | |
| 5 $\frac{3}{4}$ | 61 $\frac{1}{4}$ | 58 $\frac{1}{2}$ | 55 $\frac{3}{4}$ | 53 | 50 $\frac{3}{4}$ | 48 $\frac{1}{2}$ | 46 $\frac{1}{4}$ | 44 $\frac{1}{4}$ | 42 $\frac{1}{2}$ | 40 $\frac{3}{4}$ | 39 $\frac{1}{4}$ | 37 $\frac{3}{4}$ | 36 $\frac{1}{4}$ | 35 | |
| 6 | 62 $\frac{1}{4}$ | 59 $\frac{3}{4}$ | 57 | 54 $\frac{1}{4}$ | 52 | 49 $\frac{1}{2}$ | 47 $\frac{1}{2}$ | 45 $\frac{3}{4}$ | 43 $\frac{3}{4}$ | 42 | 40 $\frac{1}{4}$ | 39 | 37 $\frac{1}{2}$ | 36 $\frac{1}{4}$ | |

WORM THREAD HELIX ANGLES—II

| Lead of Worm, Inches | Pitch Line Diameter of Worm, Inches. (Continued). | | | | | | | | | | | | | | |
|----------------------|---|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|
| | $2\frac{3}{4}$ | $2\frac{7}{8}$ | 3 | $3\frac{1}{8}$ | $3\frac{1}{4}$ | $3\frac{3}{8}$ | $3\frac{1}{2}$ | $3\frac{5}{8}$ | $3\frac{3}{4}$ | $3\frac{7}{8}$ | 4 | $4\frac{1}{8}$ | $4\frac{1}{4}$ | $4\frac{3}{8}$ | |
| $\frac{1}{4}$ | $1\frac{3}{4}$ | $1\frac{1}{2}$ | $1\frac{1}{2}$ | $1\frac{1}{2}$ | $1\frac{1}{2}$ | $1\frac{1}{2}$ | $1\frac{1}{2}$ | $1\frac{1}{4}$ | $1\frac{1}{4}$ | $1\frac{1}{4}$ | $1\frac{1}{4}$ | $1\frac{1}{4}$ | $1\frac{1}{4}$ | $1\frac{1}{4}$ | 1 |
| $\frac{3}{8}$ | $2\frac{1}{2}$ | $2\frac{1}{2}$ | $2\frac{1}{4}$ | $2\frac{1}{4}$ | $2\frac{1}{4}$ | 2 | 2 | 2 | 2 | 2 | $1\frac{3}{4}$ | $1\frac{3}{4}$ | $1\frac{3}{4}$ | $1\frac{3}{4}$ | $1\frac{1}{2}$ |
| $\frac{1}{2}$ | $3\frac{1}{4}$ | $3\frac{1}{4}$ | 3 | 3 | $2\frac{3}{4}$ | $2\frac{3}{4}$ | $2\frac{1}{2}$ | $2\frac{1}{2}$ | $2\frac{1}{2}$ | $2\frac{1}{2}$ | $2\frac{1}{4}$ | $2\frac{1}{4}$ | $2\frac{1}{4}$ | $2\frac{1}{4}$ | 2 |
| $\frac{5}{8}$ | $4\frac{1}{4}$ | 4 | $3\frac{3}{4}$ | $3\frac{3}{4}$ | $3\frac{1}{2}$ | $3\frac{1}{2}$ | $3\frac{1}{4}$ | $3\frac{1}{4}$ | 3 | 3 | $2\frac{3}{4}$ | $2\frac{3}{4}$ | $2\frac{3}{4}$ | $2\frac{3}{4}$ | $2\frac{1}{2}$ |
| $\frac{3}{4}$ | 5 | $4\frac{3}{4}$ | $4\frac{1}{2}$ | $4\frac{1}{2}$ | $4\frac{1}{4}$ | $4\frac{1}{4}$ | 4 | $3\frac{3}{4}$ | $3\frac{3}{4}$ | $3\frac{1}{2}$ | $3\frac{1}{4}$ | $3\frac{1}{4}$ | $3\frac{1}{4}$ | $3\frac{1}{4}$ | $3\frac{1}{4}$ |
| $\frac{7}{8}$ | $5\frac{3}{4}$ | $5\frac{1}{2}$ | $5\frac{1}{4}$ | 5 | 5 | $4\frac{3}{4}$ | $4\frac{1}{2}$ | $4\frac{1}{2}$ | $4\frac{1}{4}$ | $4\frac{1}{4}$ | 4 | 4 | 4 | 4 | $3\frac{3}{4}$ |
| 1 | $6\frac{3}{4}$ | $6\frac{1}{4}$ | 6 | $5\frac{3}{4}$ | $5\frac{1}{2}$ | $5\frac{1}{2}$ | $5\frac{1}{4}$ | 5 | 5 | $4\frac{3}{4}$ | $4\frac{1}{2}$ | $4\frac{1}{2}$ | $4\frac{1}{2}$ | $4\frac{1}{2}$ | $4\frac{1}{4}$ |
| $1\frac{1}{8}$ | $7\frac{1}{2}$ | $7\frac{1}{4}$ | $6\frac{3}{4}$ | $6\frac{1}{2}$ | $6\frac{1}{4}$ | 6 | 6 | $5\frac{3}{4}$ | $5\frac{1}{2}$ | $5\frac{1}{2}$ | $5\frac{1}{4}$ | 5 | 5 | 5 | $4\frac{3}{4}$ |
| $1\frac{1}{4}$ | $8\frac{1}{4}$ | 8 | $7\frac{3}{4}$ | $7\frac{1}{2}$ | 7 | $6\frac{3}{4}$ | $6\frac{1}{2}$ | $6\frac{1}{4}$ | 6 | 6 | $5\frac{3}{4}$ | $5\frac{1}{2}$ | $5\frac{1}{2}$ | $5\frac{1}{2}$ | $5\frac{1}{4}$ |
| $1\frac{3}{8}$ | 9 | $8\frac{3}{4}$ | $8\frac{1}{4}$ | 8 | $7\frac{3}{4}$ | $7\frac{1}{2}$ | 7 | 7 | $6\frac{3}{4}$ | $6\frac{1}{2}$ | $6\frac{1}{4}$ | 6 | 6 | 6 | $5\frac{3}{4}$ |
| $1\frac{1}{2}$ | 10 | $9\frac{1}{2}$ | 9 | $8\frac{3}{4}$ | $8\frac{1}{2}$ | 8 | $7\frac{3}{4}$ | $7\frac{1}{2}$ | $7\frac{1}{4}$ | 7 | $6\frac{3}{4}$ | $6\frac{1}{2}$ | $6\frac{1}{2}$ | $6\frac{1}{2}$ | $6\frac{1}{4}$ |
| $1\frac{5}{8}$ | $10\frac{3}{4}$ | $10\frac{1}{4}$ | $9\frac{3}{4}$ | $9\frac{1}{2}$ | 9 | $8\frac{3}{4}$ | $8\frac{1}{2}$ | $8\frac{1}{4}$ | 8 | $7\frac{3}{4}$ | $7\frac{1}{2}$ | $7\frac{1}{4}$ | 7 | 7 | $6\frac{3}{4}$ |
| $1\frac{3}{4}$ | $11\frac{1}{2}$ | 11 | $10\frac{1}{2}$ | 10 | $9\frac{3}{4}$ | $9\frac{1}{2}$ | 9 | $8\frac{3}{4}$ | $8\frac{1}{2}$ | $8\frac{1}{4}$ | 8 | $7\frac{3}{4}$ | $7\frac{1}{2}$ | $7\frac{1}{4}$ | $7\frac{1}{4}$ |
| $1\frac{7}{8}$ | $12\frac{1}{4}$ | $11\frac{3}{4}$ | $11\frac{1}{4}$ | 11 | $10\frac{1}{2}$ | 10 | $9\frac{3}{4}$ | $9\frac{1}{2}$ | 9 | $8\frac{3}{4}$ | $8\frac{1}{2}$ | $8\frac{1}{4}$ | 8 | 8 | $7\frac{3}{4}$ |
| 2 | $13\frac{1}{4}$ | $12\frac{1}{2}$ | 12 | $11\frac{1}{2}$ | 11 | $10\frac{3}{4}$ | $10\frac{1}{2}$ | 10 | $9\frac{3}{4}$ | $9\frac{1}{2}$ | 9 | $8\frac{3}{4}$ | $8\frac{1}{2}$ | $8\frac{1}{4}$ | $8\frac{1}{2}$ |
| $2\frac{1}{4}$ | $14\frac{3}{4}$ | 14 | $13\frac{1}{2}$ | 13 | $12\frac{1}{2}$ | 12 | $11\frac{1}{2}$ | $11\frac{1}{4}$ | 11 | $10\frac{1}{2}$ | $10\frac{1}{4}$ | 10 | $9\frac{1}{2}$ | $9\frac{1}{4}$ | $9\frac{1}{2}$ |
| $2\frac{1}{2}$ | $16\frac{1}{4}$ | $15\frac{1}{2}$ | 15 | $14\frac{1}{4}$ | $13\frac{3}{4}$ | $13\frac{1}{2}$ | $12\frac{3}{4}$ | $12\frac{1}{2}$ | 12 | $11\frac{3}{4}$ | $11\frac{1}{4}$ | 11 | $10\frac{3}{4}$ | $10\frac{1}{2}$ | $10\frac{1}{2}$ |
| $2\frac{3}{4}$ | $17\frac{3}{4}$ | 17 | $16\frac{1}{4}$ | $15\frac{3}{4}$ | 15 | $14\frac{3}{4}$ | 14 | $13\frac{3}{4}$ | $13\frac{1}{4}$ | $12\frac{3}{4}$ | $12\frac{1}{4}$ | 12 | $11\frac{3}{4}$ | $11\frac{1}{2}$ | $11\frac{1}{2}$ |
| 3 | $19\frac{1}{4}$ | $18\frac{1}{2}$ | $17\frac{3}{4}$ | 17 | $16\frac{1}{2}$ | 16 | $15\frac{1}{4}$ | 15 | $14\frac{1}{2}$ | 14 | $13\frac{1}{2}$ | 13 | 13 | 13 | $12\frac{1}{4}$ |
| $3\frac{1}{4}$ | $20\frac{3}{4}$ | $19\frac{3}{4}$ | 19 | $18\frac{1}{2}$ | $17\frac{3}{4}$ | 17 | $16\frac{1}{2}$ | 16 | $15\frac{1}{2}$ | 15 | $14\frac{1}{2}$ | $14\frac{1}{4}$ | 14 | 14 | $13\frac{1}{4}$ |
| $3\frac{1}{2}$ | 22 | $21\frac{1}{4}$ | $20\frac{1}{2}$ | $19\frac{1}{2}$ | 19 | $18\frac{1}{4}$ | $17\frac{3}{4}$ | $17\frac{1}{4}$ | $16\frac{3}{4}$ | 16 | $15\frac{1}{2}$ | $15\frac{1}{2}$ | 15 | 15 | $14\frac{1}{4}$ |
| $3\frac{3}{4}$ | $23\frac{1}{2}$ | $22\frac{1}{2}$ | $21\frac{3}{4}$ | 21 | $20\frac{1}{4}$ | $19\frac{1}{2}$ | 19 | $18\frac{1}{2}$ | 18 | $17\frac{1}{4}$ | $16\frac{1}{2}$ | $16\frac{1}{4}$ | $15\frac{3}{4}$ | $15\frac{1}{4}$ | $15\frac{1}{4}$ |
| 4 | 25 | 24 | 23 | 22 | $21\frac{1}{2}$ | $20\frac{3}{4}$ | 20 | $19\frac{1}{2}$ | 19 | $18\frac{1}{2}$ | $17\frac{1}{2}$ | $17\frac{1}{4}$ | $16\frac{3}{4}$ | $16\frac{1}{4}$ | $16\frac{1}{4}$ |
| $4\frac{1}{4}$ | $26\frac{1}{4}$ | $25\frac{1}{4}$ | $24\frac{1}{4}$ | $23\frac{1}{2}$ | $22\frac{1}{2}$ | 22 | $21\frac{1}{4}$ | $20\frac{1}{2}$ | 20 | $19\frac{1}{2}$ | $18\frac{1}{2}$ | $18\frac{1}{2}$ | $17\frac{3}{4}$ | $17\frac{1}{4}$ | $17\frac{1}{4}$ |
| $4\frac{1}{2}$ | $27\frac{1}{2}$ | $26\frac{1}{2}$ | $25\frac{1}{2}$ | $24\frac{1}{2}$ | $23\frac{3}{4}$ | 23 | $22\frac{1}{2}$ | $21\frac{1}{2}$ | 21 | $20\frac{1}{2}$ | $19\frac{3}{4}$ | $19\frac{1}{2}$ | $18\frac{1}{2}$ | $18\frac{1}{4}$ | $18\frac{1}{4}$ |
| $4\frac{3}{4}$ | 29 | $27\frac{3}{4}$ | $26\frac{3}{4}$ | $25\frac{3}{4}$ | 25 | 24 | $23\frac{1}{2}$ | $22\frac{3}{4}$ | 22 | $21\frac{1}{2}$ | $20\frac{3}{4}$ | $20\frac{1}{2}$ | $19\frac{1}{2}$ | $19\frac{1}{4}$ | $19\frac{1}{4}$ |
| 5 | $30\frac{1}{4}$ | 29 | 28 | 27 | 26 | $25\frac{1}{4}$ | $24\frac{1}{2}$ | $23\frac{3}{4}$ | 23 | $22\frac{1}{2}$ | $21\frac{3}{4}$ | $21\frac{1}{4}$ | $20\frac{1}{2}$ | 20 | 20 |
| $5\frac{1}{4}$ | $31\frac{1}{2}$ | $30\frac{1}{4}$ | 29 | $28\frac{1}{4}$ | 27 | $26\frac{1}{2}$ | $25\frac{1}{2}$ | $24\frac{3}{4}$ | 24 | $23\frac{1}{2}$ | $22\frac{1}{2}$ | 22 | $21\frac{1}{2}$ | $21\frac{1}{4}$ | 21 |
| $5\frac{1}{2}$ | $32\frac{3}{4}$ | $31\frac{1}{2}$ | $30\frac{1}{4}$ | $29\frac{1}{4}$ | $28\frac{1}{4}$ | $27\frac{1}{2}$ | $26\frac{1}{2}$ | $25\frac{3}{4}$ | $25\frac{1}{4}$ | $24\frac{1}{2}$ | $23\frac{1}{2}$ | 23 | $22\frac{1}{2}$ | $22\frac{1}{4}$ | 22 |
| $5\frac{3}{4}$ | $33\frac{3}{4}$ | $32\frac{1}{2}$ | $31\frac{1}{2}$ | $30\frac{1}{4}$ | $29\frac{1}{2}$ | $28\frac{1}{2}$ | $27\frac{3}{4}$ | 27 | $26\frac{1}{4}$ | $25\frac{1}{2}$ | $24\frac{1}{2}$ | 24 | $23\frac{1}{2}$ | $23\frac{1}{4}$ | 23 |
| 6 | 35 | $33\frac{3}{4}$ | $32\frac{1}{2}$ | $31\frac{1}{2}$ | $30\frac{1}{2}$ | $29\frac{1}{2}$ | $28\frac{3}{4}$ | $27\frac{3}{4}$ | 27 | $26\frac{1}{2}$ | $25\frac{1}{2}$ | 25 | $24\frac{1}{4}$ | $23\frac{3}{4}$ | $23\frac{3}{4}$ |

WORM THREAD HELIX ANGLES—III

| Lead of Worm, Inches | Pitch Line Diameter of Worm, Inches. (Continued). | | | | | | | | | | | | | |
|----------------------|---|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|--|
| | $4\frac{1}{2}$ | $4\frac{5}{8}$ | $4\frac{3}{4}$ | $4\frac{7}{8}$ | 5 | $5\frac{1}{8}$ | $5\frac{1}{4}$ | $5\frac{3}{8}$ | $5\frac{1}{2}$ | $5\frac{5}{8}$ | $5\frac{3}{4}$ | $5\frac{7}{8}$ | 6 | |
| $\frac{1}{4}$ | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | |
| $\frac{3}{8}$ | $1\frac{1}{2}$ | $1\frac{1}{2}$ | $1\frac{1}{2}$ | $1\frac{1}{2}$ | $1\frac{1}{2}$ | $1\frac{1}{2}$ | $1\frac{1}{2}$ | $1\frac{1}{4}$ | $1\frac{1}{4}$ | $1\frac{1}{4}$ | $1\frac{1}{4}$ | $1\frac{1}{4}$ | $1\frac{1}{4}$ | |
| $\frac{1}{2}$ | 2 | 2 | 2 | 2 | 2 | 2 | 2 | $1\frac{3}{4}$ | $1\frac{3}{4}$ | $1\frac{3}{4}$ | $1\frac{3}{4}$ | $1\frac{3}{4}$ | $1\frac{1}{2}$ | |
| $\frac{5}{8}$ | $2\frac{1}{2}$ | $2\frac{1}{2}$ | $2\frac{1}{2}$ | $2\frac{1}{2}$ | $2\frac{1}{4}$ | $2\frac{1}{4}$ | $2\frac{1}{4}$ | $2\frac{1}{4}$ | $2\frac{1}{4}$ | $2\frac{1}{4}$ | 2 | 2 | 2 | |
| $\frac{3}{4}$ | 3 | 3 | 3 | 3 | $2\frac{3}{4}$ | $2\frac{3}{4}$ | $2\frac{3}{4}$ | $2\frac{3}{4}$ | $2\frac{1}{2}$ | $2\frac{1}{2}$ | $2\frac{1}{4}$ | $2\frac{1}{4}$ | $2\frac{1}{4}$ | |
| $\frac{7}{8}$ | $3\frac{1}{2}$ | $3\frac{1}{2}$ | $3\frac{1}{2}$ | $3\frac{1}{4}$ | $3\frac{1}{4}$ | $3\frac{1}{4}$ | 3 | 3 | 3 | $2\frac{3}{4}$ | $2\frac{3}{4}$ | $2\frac{3}{4}$ | $2\frac{3}{4}$ | |
| 1 | 4 | 4 | $3\frac{3}{4}$ | $3\frac{3}{4}$ | $3\frac{3}{4}$ | $3\frac{1}{2}$ | $3\frac{1}{2}$ | $3\frac{1}{2}$ | $3\frac{1}{4}$ | $3\frac{1}{4}$ | $3\frac{1}{4}$ | $3\frac{1}{4}$ | 3 | |
| $1\frac{1}{8}$ | $4\frac{1}{2}$ | $4\frac{1}{2}$ | $4\frac{1}{4}$ | $4\frac{1}{4}$ | $4\frac{1}{4}$ | 4 | 4 | $3\frac{3}{4}$ | $3\frac{3}{4}$ | $3\frac{3}{4}$ | $3\frac{3}{4}$ | $3\frac{1}{2}$ | $3\frac{1}{2}$ | |
| $1\frac{1}{4}$ | 5 | 5 | $4\frac{3}{4}$ | $4\frac{3}{4}$ | $4\frac{1}{2}$ | $4\frac{1}{2}$ | $4\frac{1}{2}$ | $4\frac{1}{4}$ | $4\frac{1}{4}$ | $4\frac{1}{4}$ | 4 | 4 | $3\frac{3}{4}$ | |
| $1\frac{3}{8}$ | $5\frac{1}{2}$ | $5\frac{1}{2}$ | $5\frac{1}{4}$ | $5\frac{1}{4}$ | 5 | 5 | $4\frac{3}{4}$ | $4\frac{3}{4}$ | $4\frac{1}{2}$ | $4\frac{1}{2}$ | $4\frac{1}{2}$ | $4\frac{1}{4}$ | $4\frac{1}{4}$ | |
| $1\frac{1}{2}$ | 6 | 6 | $5\frac{3}{4}$ | $5\frac{1}{2}$ | $5\frac{1}{2}$ | $5\frac{1}{4}$ | $5\frac{1}{4}$ | 5 | 5 | $4\frac{3}{4}$ | $4\frac{3}{4}$ | $4\frac{3}{4}$ | $4\frac{1}{2}$ | |
| $1\frac{5}{8}$ | $6\frac{1}{2}$ | $6\frac{1}{2}$ | $6\frac{1}{4}$ | 6 | 6 | $5\frac{3}{4}$ | $5\frac{3}{4}$ | $5\frac{1}{2}$ | $5\frac{1}{2}$ | $5\frac{1}{4}$ | $5\frac{1}{4}$ | 5 | 5 | |
| $1\frac{3}{4}$ | 7 | 7 | $6\frac{3}{4}$ | $6\frac{1}{2}$ | $6\frac{1}{2}$ | $6\frac{1}{4}$ | 6 | 6 | $5\frac{3}{4}$ | $5\frac{3}{4}$ | $5\frac{1}{2}$ | $5\frac{1}{2}$ | $5\frac{1}{2}$ | |
| $1\frac{7}{8}$ | $7\frac{1}{2}$ | $7\frac{1}{2}$ | $7\frac{1}{4}$ | 7 | 7 | $6\frac{3}{4}$ | $6\frac{1}{2}$ | $6\frac{1}{2}$ | $6\frac{1}{4}$ | 6 | 6 | $5\frac{3}{4}$ | $5\frac{3}{4}$ | |
| 2 | $8\frac{1}{4}$ | 8 | $7\frac{3}{4}$ | $7\frac{1}{2}$ | $7\frac{1}{4}$ | $7\frac{1}{4}$ | 7 | $6\frac{3}{4}$ | $6\frac{3}{4}$ | $6\frac{1}{2}$ | $6\frac{1}{2}$ | $6\frac{1}{4}$ | 6 | |
| $2\frac{1}{4}$ | 9 | 9 | $8\frac{3}{4}$ | $8\frac{1}{2}$ | $8\frac{1}{4}$ | 8 | 8 | $7\frac{3}{4}$ | $7\frac{1}{2}$ | $7\frac{1}{2}$ | $7\frac{1}{4}$ | 7 | 7 | |
| $2\frac{1}{2}$ | 10 | 10 | $9\frac{1}{2}$ | $9\frac{1}{4}$ | $9\frac{1}{4}$ | 9 | $8\frac{3}{4}$ | $8\frac{1}{2}$ | $8\frac{1}{4}$ | $8\frac{1}{4}$ | 8 | $7\frac{3}{4}$ | $7\frac{1}{2}$ | |
| $2\frac{3}{4}$ | 11 | $10\frac{3}{4}$ | $10\frac{1}{2}$ | $10\frac{1}{4}$ | 10 | $9\frac{3}{4}$ | $9\frac{1}{2}$ | $9\frac{1}{4}$ | $9\frac{1}{4}$ | 9 | $8\frac{3}{4}$ | $8\frac{1}{2}$ | $8\frac{1}{2}$ | |
| 3 | 12 | $11\frac{1}{2}$ | $11\frac{1}{2}$ | 11 | 11 | $10\frac{3}{4}$ | $10\frac{1}{2}$ | $10\frac{1}{4}$ | 10 | $9\frac{3}{4}$ | $9\frac{1}{2}$ | $9\frac{1}{2}$ | $9\frac{1}{4}$ | |
| $3\frac{1}{4}$ | 13 | $12\frac{1}{2}$ | $12\frac{1}{4}$ | 12 | $11\frac{3}{4}$ | $11\frac{1}{2}$ | 11 | 11 | $10\frac{3}{4}$ | $10\frac{1}{2}$ | $10\frac{1}{4}$ | $10\frac{1}{4}$ | 10 | |
| $3\frac{1}{2}$ | 14 | $13\frac{1}{2}$ | $13\frac{1}{4}$ | 13 | $12\frac{1}{2}$ | $12\frac{1}{4}$ | 12 | $11\frac{3}{4}$ | $11\frac{1}{2}$ | $11\frac{1}{4}$ | 11 | $10\frac{3}{4}$ | $10\frac{1}{2}$ | |
| $3\frac{3}{4}$ | 15 | $14\frac{1}{2}$ | $14\frac{1}{4}$ | $13\frac{3}{4}$ | $13\frac{1}{2}$ | 13 | 13 | $12\frac{1}{2}$ | $12\frac{1}{4}$ | 12 | $11\frac{3}{4}$ | $11\frac{1}{2}$ | $11\frac{1}{4}$ | |
| 4 | 16 | $15\frac{1}{2}$ | 15 | $14\frac{1}{2}$ | $14\frac{1}{4}$ | 14 | $13\frac{3}{4}$ | $13\frac{1}{4}$ | 13 | 13 | $12\frac{1}{2}$ | $12\frac{1}{4}$ | 12 | |
| $4\frac{1}{4}$ | $16\frac{3}{4}$ | $16\frac{1}{2}$ | 16 | $15\frac{1}{2}$ | $15\frac{1}{4}$ | 15 | $14\frac{1}{2}$ | 14 | 14 | $13\frac{3}{4}$ | $13\frac{1}{2}$ | 13 | $12\frac{3}{4}$ | |
| $4\frac{1}{2}$ | $17\frac{1}{2}$ | $17\frac{1}{4}$ | 17 | $16\frac{1}{2}$ | 16 | $15\frac{3}{4}$ | $15\frac{1}{4}$ | 15 | $14\frac{3}{4}$ | $14\frac{1}{2}$ | $14\frac{1}{4}$ | $13\frac{3}{4}$ | $13\frac{1}{2}$ | |
| $4\frac{3}{4}$ | $18\frac{1}{2}$ | $18\frac{1}{4}$ | 18 | $17\frac{1}{4}$ | 17 | $16\frac{1}{2}$ | 16 | 16 | $15\frac{1}{2}$ | $15\frac{1}{4}$ | 15 | $14\frac{1}{2}$ | $14\frac{1}{4}$ | |
| 5 | $19\frac{1}{2}$ | 19 | $18\frac{1}{2}$ | $18\frac{1}{4}$ | 18 | $17\frac{1}{4}$ | 17 | $16\frac{1}{2}$ | $16\frac{1}{4}$ | 16 | $15\frac{1}{2}$ | $15\frac{1}{4}$ | 15 | |
| $5\frac{1}{4}$ | $20\frac{1}{2}$ | 20 | $19\frac{1}{2}$ | 19 | $18\frac{1}{2}$ | $18\frac{1}{4}$ | $17\frac{3}{4}$ | $17\frac{1}{2}$ | 17 | $16\frac{3}{4}$ | $16\frac{1}{4}$ | 16 | $15\frac{3}{4}$ | |
| $5\frac{1}{2}$ | $21\frac{1}{2}$ | 21 | $20\frac{1}{2}$ | 20 | $19\frac{1}{2}$ | 19 | $18\frac{1}{2}$ | $18\frac{1}{4}$ | 18 | $17\frac{1}{2}$ | 17 | $16\frac{3}{4}$ | $16\frac{1}{2}$ | |
| $5\frac{3}{4}$ | 22 | $21\frac{3}{4}$ | 21 | $20\frac{1}{2}$ | $20\frac{1}{4}$ | $19\frac{3}{4}$ | $19\frac{1}{2}$ | 19 | $18\frac{1}{2}$ | $18\frac{1}{4}$ | $17\frac{3}{4}$ | $17\frac{1}{2}$ | 17 | |
| 6 | 23 | $22\frac{1}{2}$ | 22 | $21\frac{1}{2}$ | 21 | $20\frac{1}{2}$ | 20 | $19\frac{1}{2}$ | $19\frac{1}{4}$ | 19 | $18\frac{1}{2}$ | 18 | $17\frac{3}{4}$ | |

inches, which is then the required lead of the spiral.

If the lead and the angle are given, the diameter can be found, and if the diameter and lead are given the angle can be found as indicated in the notes beneath the tables. For example, assume that the lead is 8 inches and the diameter 5 inches. Then divide the given lead by the given diameter and find the quotient in the body of the table; $8 \div 5 = 1.6$. The angle corresponding to this lead, which is the lead for diameter 1, is found in the table on page 19 to equal 63 degrees very nearly.

Assume that a spiral angle of 75 degrees 30 minutes and a lead of 4.06 inches are given. Then the diameter is found by dividing the given lead 4.06 with the value of L corresponding to 75 degrees 30 minutes as given in the table, this value being 0.812. The diameter then equals $4.06 \div 0.812 = 5$ inches.

Constants for Calculating Spiral Gears

The calculation of spiral gears is a time-consuming operation, and any short-cuts or labor-saving methods are eagerly accepted by designers. On pages 20 to 23, inclusive, are given constants for calculating spiral gears, the use of which will materially reduce the time necessary for the computation of the angles and dimensions of spiral gears. The body of the tables gives constants C_t ($=$ center distance of shafts per tooth of pinion) for each speed ratio given, the shafts being at right angles, while factors U , F and L are equally applicable to gears on shafts at any angle. The constants for unit diameter of gear per tooth, U , and for unit center distance per tooth of fastest running gear, C_t , are calculated for gears cut with spur gear cutters of one diametral pitch. For any other pitch, divide the constant by the diametral pitch of the cutter used. The factors C_t given in the body of the tables are, it should

be noted, per tooth of fastest running gear, or gear having the smallest number of teeth. All factors are given for each degree from 12 to 78 degrees of angle of tooth helix. While strict accuracy would require interpolation, for angles including a fractional part of a degree, test calculations have shown that a simple proportional value between the factors is sufficiently accurate to meet all practical requirements. The examples of the use of the tables given directly beneath them, together with the formulas in the explanatory note on page 20 will make the use of the tables clear. [MACHINERY, December, 1908, Constants for Calculating Helical Gears.]

Cutters for Milling Spiral Gears

A convenient diagram for finding the cutters for milling the teeth of spiral gears is given on page 24, together with a complete description of the method of using the diagram. As the formula for finding the cutter to use involves the cosine of the tooth angle in the third power, and hence requires considerable calculation, the simplicity of the use of this diagram will be appreciated.

Dimensions of Worm Gearing

In giving names to the dimensions of the worm, there is one point which sometimes causes confusion. This relates to the definitions of the terms "pitch" and "lead." The word "lead" means the distance which a given thread advances in one revolution of the worm, while the "pitch," or more strictly, the "linear pitch," is the distance from center to center of two adjacent threads. It is evident that the lead and linear pitch are equal for a single-threaded worm; for a double-threaded worm the lead is twice the linear pitch, and for a triple-threaded worm it is three times the linear pitch.

When the number of threads in a worm is spoken of, the number of threads per inch is not referred to, but

the number of threads in the whole worm, that is, one if it is single-threaded, four if it is quadruple-threaded, etc.

On page 25 are given rules and formulas for the calculations of the dimensions of worm gearing, arranged in a manner similar to the rules for bevel gearing on pages 4 and 5. The numbers in the columns to the left are given for convenience in referring to the various rules and formulas only. The notation used in the formulas is easily determined by a comparison with the rules written out in words. On page 26 is given a table for worms and worm gearing in general, giving calculated values for the various dimensions. The formulas given at the head of the columns of dimensions are those by means of which the dimensions below have been calculated.

The rules given on page 25 are sometimes departed from. The throat diameter of the wheel and the center distance may have to be altered in some cases. For example, if worm-wheels with small numbers of teeth are made to the dimensions found from the rules and formulas, it will be found that the flanks of the teeth will be partly cut away by the tops of the hob teeth, so that a full bearing area is not available. This latter affects the worm-wheel drive seriously when there are less than twenty-five teeth in the worm-wheel. There are two ways of avoiding this difficulty. One may increase the in-

cluded angle of the sides of the thread-tool by which the hob is cut. This departure from the standard form, however, may be avoided by an increase in the throat diameter of the wheel, and consequently in the center distance. Some designers, again, claim to obtain better results in efficiency and durability by making the throat diameter of the worm-wheel smaller than standard, when it is possible to do so without too much under-cutting. In no case, however, should the throat diameter ever be made so small as to produce more interference than is met with in a standard 25-tooth worm-wheel. [MACHINERY, August, 1907, Calculating the dimensions of Worm Gearing; MACHINERY's Reference Series No. 1, Worm Gearing, Chapter I.]

Worm Thread Helix Angles

In the body of the tables on pages 28 to 30 are given the approximate angles of the thread of worms when the lead of the worm and the pitch line diameter of the worm in inches are given. For example: If the lead of the worm is one inch and its pitch line diameter 2 inches, then the angle of helix is approximately 9 inches, as shown in the table on page 28. These tables can, of course, be used in a reverse order. If the angle in degrees and the pitch line diameter are known, the approximate lead may be found, and if the lead and angle are known the approximate diameter may be located.

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